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THE EDUCATION OF ELECTRICAL APPRENTICES AND JOURNEYMEN.

BY ARTHUR A. HAMERSCHLAG.

I am leaving to a certain extent the beaten path of precedent by giving the INSTITUTE a lecture on a subject which is neither pure science nor engineering. It is because of the importance of the subject and the influence it will exert on the future of the electrical industry that I have been bold enough to broach it. I do so with the hope that some agitation and discussion will point out a solution of a problem which becomes of more vital importance each year:—That of securing the necessary skilled mechanics requisite to the execution of electrical engineering works in a satisfactory and efficient manner.

The world has watched with startled eyes the rapid and far-reaching strides the young electrical industry has made, and the numerous fields in which electricity has entered. Scarcely a decade has passed since the industry, with justice, was called an infant. From a total investment of a few thousand dollars, it has to-day grown to such proportions that it would be impossible to compute with accuracy the value of the various industries in which electricity plays a prominent part. It is almost as difficult to assimilate the figures of value in their proper proportion as it is to define the widening field they have developed for skilled electrical labor. From an industry that gave employment to a few hundred men, in a decade it has expanded until to day it demands the services of tens of thousands of men devoting their services exclusively to this work. It has also demanded men of intelligence of a comparatively high order, well equipped with

mechanical skill. That we have made such astonishing progress is remarkable, but not nearly so wonderful as that we have found in the past, men in sufficiently large numbers capable of devising, developing and manufacturing electrical products on a marketable basis.

Should another generation find a proportional increase in the demand for electrical products and operations (and the prospects are good for such an increase) shall we be equally fortunate in finding the skilled men necessary? Is it just as certain these men will be found? It is the doubt that the condition will be so easily mastered that has given me the courage to speak to you to-night on this subject.

The birth of an industry is not the most potent factor in determining its development; it needs the nourishment and care of those engaged in it to enable it grow to maturity. With its growth it must develop and nurture the individuals upon whom it most depends. Merit alone will not enable it to be perpetuated and put upon a successful basis unless it is capable of placing its raw material in the hands of skilled workers upon whom absolute dependence can be placed.

It is to develop this most essential factor of future success that I believe it time that we give a thought to meeting the coming demand by educating the apprentices and journeymen to that point which will make it possible for our boldest conceptions in electro-technics to be skilfully and economically solved.

As we draw near the closing days of the century—a hundred years pregnant with progress and events, none is more notable in the world of science than electrical achievements. A thought and a backward glance will show American supremacy in this field. In order however to retain this supremacy we cannot afford to rest content with the laurels we have won, else they will be wrested from us.

The old world has given us excellent mechanics through its apprenticeship system: unfortunately even in those countries that system is dying out. This country has never had a well-developed apprenticeship system, and to-day it has almost entirely disappeared because of the peculiar restrictions placed thereon by the unions and associations, and the centralizations of the work under single financial heads, paying men by the hour or day, leading employees to shift from place to place as the demand for their services varies from busy to dull times. In fact to-day the

apprenticeship system is almost impossible for financial and other reasons, so we must devise some other means of educating the youth who wishes to enter the electrical field.

It is true that three or four of the largest electrical concerns do apprentice young men but the number is comparatively small, and it requires considerable influence to secure such indentures. The number of applicants is, however, out of all proportion to the number that can be accommodated, and such openings are almost entirely out of the reach of the vast majority because of isolated location.

Electrical work as a trade and as a profession is now undergoing the same trials and tribulations regarding educational means that other trades and professions have undergone in the past, except that the problem in the electrical industry owing to its rapid growth is of vastly greater urgency. Because of this growth along scientific and mechanical lines, improvements succeed improvements so rapidly that what was considered good practice yesterday becomes obsolete and defective to-morrow. The men are mechanics who but a few years ago handled cleats and mouldings in wiring, but are to-day asked to use iron pipe and conduit requiring entirely different tools, materials and methods. And where do these men acquire the efficiency and facility for this work? They acquire it in the crudest and most wasteful method possible, by experimentally using their employers' material, and at his expense in the time during which he is compelled to pay for skilled labor. These improvements certainly result in the loss of the journeymen's efficiency, and result in "rule of thumb" mechanics. This type of mechanic is to be found in all trades, and sometimes he is exceptionally skilled in his work and thus causes a tendency on the part of employers to desire more of him or men like him, especially when he is placed side by side with the so-called theoretical mechanic who lacks the skill.

The fallacy of this reasoning is at once apparent when the "rule of thumb" mechanics come in competition with the well grounded and educated mechanics who possess an equal amount of skill. Then the efficiency of the latter is so much greater, that there can be no comparison. Oftentimes we meet men with such a vast preponderance of theoretical training, that it has removed the inherent practical skill, and this type of journeyman is almost useless when judged from the working standpoint. This latter

condition is not a rare one by any means and just a few words concerning it may be appropriate.

A glance over a list of our numerous educational institutions causes us to feel proud of our achievements in this line. In almost every settlement or city throughout the country, some school, college or university is supported upon as lavish a scale as one could desire. Endless seem the opportunities which the young American has, to acquire the learning and higher education which are prized and cherished in the world to-day. We have schools for every conceivable purpose; we have colleges and universities for every profession, and we have technical institutions almost unmatched in efficiency. But we have only a very few practical trade schools, and for the education of electrical mechanics, fewer still. And yet, in which field can we utilize, at present and in the future, the greatest number of skilled men. In the engineering branch or in the skilled labor branch? The answer must obviously be in the latter. Still, parents will persist in sending their children, regardless of their inherent qualities, to the colleges and universities to master a profession without giving a thought to the field in which their future labors must be conducted, without considering the compensation they will receive. And what is the result? There can be only one general reply.

After years of study and much money spent in acquiring the profession, and an early association with children of wealth and refinement, the born mechanic becomes ruined for the sake of posing as a genius, or a great engineer. The field for mediocre engineers is just as narrow and confined as it is for the mediocre artist, and the compensation for his labor is correspondingly curtailed. As a result, when the young man is thrown on his own resources, he must suffer that genteel poverty which his training in refined circles has bound him to. He can no longer look with pride upon the work of his hands, and his brain power being but the average he suffers acutely, and eventually becomes neither an excellent mechanic nor an excellent engineer.

Each year the colleges and universities are sending into the world large numbers of young men, who after years of work, take the title of "Electrical Engineer." How many of these will ever have an opportunity to do any genuine electrical engineering. How many of them are destined never to earn, in the electrical line, $1.000 or so a year, the pay of a skilled mechanic.

For every single opening for an electrical engineer, there are

a hundred openings for the skilled journeyman, and for every successful engineer there are a hundred successful journeymen. And to be a journeyman does not mean to be debarred from engineering.

Who have made the notable inventions, who have carried out the greatest engineering problems? Not the trained engineer, but the journeymen who have started at the bottom and by their individual efforts raised themselves to the highest level. "By their deeds ye shall judge them," is true of men, whether they have been educated up to a high standard or not, and self-training is often the more effective.

The compensation for skilled electrical labor, such as journeymen bring into the market, has been on the increase, it will continue to increase, and in an unfair degree unless employers think in time of a method of supplying the increasing demand, or of making the labor which is offered, worth the increase, in results achieved.

Every new electrical equipment, each railroad equipped electrically, and each industry which depends on electricity, is taking some of our skilled men from the open market and retaining them permanently, and confining their energy to maintaining such equipment.

Whence will come the men to replace these defections. Has no one a solution to offer as to the best way of replenishing the supply? Many methods of solving this problem have been tried, some of them without proper consideration of the case.

Some have been the education of journeymen in other trades, such as carpenters, draughtsmen, etc., by means of actual experience during their employers' time, a poor means at best, and which places the burden directly on the shoulders of the employers, while the resultant mechanic leaves much to be desired in all around efficiency.

Oftentimes untried young men with the desire to be electrical artisans attend, in a desultory fashion, popular lecture courses, witness a few experiments in static and galvanic electricity and find them of such interest that even though they possess little or no qualifications, and have been educated and trained for other lines they determine to make electricity their life work. Their methods of securing the necessary instruction is usually a so-called apprenticeship in a shop manufacturing some article, which in itself gives them comparatively little instruction and which

makes them eventually skilled in hand work without giving them any breadth of training, and merely enables them to fill the position of a simple automatic machine.

Sometimes they read electrical lectures and trade papers, in many instances finding themselves very much at sea because of the technical character of the papers and articles, which their previous training has done nothing to enable them to understand.

Sometimes as a final resort they become recipients of the training offered by correspondence schools, and these schools are certainly gathering an ever increasing clientele which their merit justifies.

In very rare instances they attend by far the best and most modern form of securing this training, and that through the trade school. There are however such a very few of the latter institutions in spite of their acknowledged merit, and they are so little known that only a very small percentage of the number who wish to become electrical craftsmen can reap their benefits.

The superiority of the trade school for educating and equipping young men for trade work is so vastly superior to any other form of acquiring the result, that to it in the future must we look to solve this very serious problem. Foreign countries have realized this fact for many years and profited by it. Is it not time that this progressive country began to realize it also and to stimulate and support such institutions? They certainly are bound to spring into existence, and those that exist and have an honorable record are bound to improve that record, and it is but a question of time when intelligent thinkers must give them their proper place and dues.

It has been my good fortune to have been connected with trade schools for some years, notably with the New York Trade School, St. George's Evening Trade School of New York, and the Highland Falls Trade School of Highland Falls, New York. They have taught me a lesson which I hope to profit by in the future, not alone concerning the electrical industry but concerning many trades. It is a lesson however which applies in an equal measure to them all, and that is that trade schools have an equally high aim and purpose as compared with any educational institution in the country. That their field cannot be covered in any other way, and if they were accorded the same support and encouragement by the fraternity and the public that other educational institutions receive, their effect and beneficent influence

would be as widespread, if not felt in even a greater degree, because of the class which they aim to assist.

It seems strange to me that trade schools should be subject to such marked indifference by the employers, and by such intense persecution and criticism by the fraternity which they aim to assist, merely because of the possible future competition their graduates will cause when they have come to the journeyman's estate.

Was there ever a scientific institution aiming at higher education, a medical college, a law or an art school, but received the support and endorsement of the leaders of the respective professions, if its object was not to make money, but to benefit the respective branches?

Are the prominent lawyers, physicians, the artist or the men of any other profession less free from the thought of future competition than the journeymen and the employer, that the latter should be found wanting in that which tends to advance his profession?

The governing societies, the trade associations and the employers' associations must eventually see the wisdom of the trade schools, and perhaps when they realize the necessity for them and are compelled to support them, they will indeed see the error of their ways.

A society like the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, whose members comprise a very large number of the engineers engaged in electrical enterprises, can do much to bring this problem before the men of their line, and can materially assist in a solution of this problem of so much importance to the welfare of the electrical industry. The youth of the country imbued with the desire to become electricians will force their way in, and the inevitable is bound to occur. These young men will eventually enter the field of their choice. Why not help them and encourage them to enter under the best conditions and highest possible standard, instead of leaving them to drift in, unequipped, inefficient and lacking in essential requirements. Is it not the best for them to live up to the studies exacted by skilled artisans in other lines, so that they can not only become self-reliant and successful, but reflect credit on the fraternity to which they have given their allegiance.

Trade schools have in the past done much to assist young men to acquire the rudiments of trades in other lines; they have

tended to raise the standard of the individuals styling themselves helpers and journeymen, by showing the capacity of the beginner and they have put the highest premium on skill and efficiency.

What I wish to impress most seriously on my hearers, is that this question of educating apprentices and journeymen, bears a vital and urgent relation to the future success or failure of an industry in which we all feel commendable pride.

The New York Trade School, owing to the far-sightedness and philanthropy of its founder Col. R. Tylden Auchmuty, has been in the field to remedy this coming dearth of skilled mechanics and the crowding out of our home industries of the native born American workers by foreign skilled labor. Aided by the munificence of Mr. J. Pierpont Morgan and other gentlemen, it has been able to broaden its scope until to-day it ranks as the pioneer and largest trade school in the country. With its six thousand graduates it has demonstrated its utility and shown the way to those who wish to follow.

Three years ago it took cognizance of the electrical situation and immediately established a thoroughly practical course for electrical workers, which became at once an assured success, filling the class room to its fullest capacity and having a waiting list of young men eager to enter the classes.

The first year the class numbered thirty-two. The second year a large department was opened and fifty were accommodated, and still the waiting list continued to be as large. This year fifty are again at work and fully that number were turned away.

The course is thoroughly practical because nothing is taught which is not done by the students themselves and tested and proved before acceptance.

This year a course for journeymen workers in the form of practical lessons will be established. Its success is problematical but should it show any signs of growth and interest it may lead to future results which cannot fail to be of interest to the whole electrical fraternity.

The lantern slides show the classes at work and a few samples of work, but give but a vague impression of the school, which all members of the INSTITUTE are cordially invited to visit.

DISCUSSION.

THE CHAIRMAN:—Gentlemen, I think we have all been very much interested in Mr. Hamerschlag's address, treating, as it does a subject which has not heretofore been discussed by the INSTITUTE.

It seems to me that Mr. Hamerschlag has sounded a timely note in calling attention to the great demand which the growth of the electrical industry is making upon the labor market, and the desirability of training young men to be satisfactory and efficient electrical workers. This subject comes home to many of us who have had to meet the difficult problem of developing an efficient force to handle electrical work, and after listening to Mr. Hamerschlag's interesting address we shall be better prepared to give institutions of the character described by him our cordial support and co-operation. I think the subject is an extremely important one and well worthy of your careful consideration. I see we have with us this evening a number of members who have done effective work along parallel educational lines, and we should be glad to have them favor us with any remarks which the topic under discussion may suggest.

MR. JOSEPH WETZLER:—I believe Mr. Hamerschlag has stated his points so forcibly that a corroboration of his remarks is scarcely necessary. If we want to look for the right course to pursue in the education of men in strictly trade lines, I think, Germany presents the best example which the world affords. Its present commercial supremacy is certainly due to what the Germans call their Gewerbeschulen, which are pure and simple trade schools. Nearly every important industry in Germany has its trade school, from which it graduates young men who are able to take up intelligently the work of that particular trade.

It is only within a day or two that I had occasion to read the report of one of our Consuls to the State Department at Washington, in which he mentions the results achieved by those German schools. He refers particularly, however, to the report made by an English commission which had been sent over to study the industrial education problem in Germany. I take the following quotation from the Consular Report.

"Under such mental and manual training, with steadily improving machinery, a class of highly intelligent workmen has been developed which in their several lines are nowhere surpassed, if equaled. This is true to such an extent, that a commission of Englishmen, which had been sent to Germany to inspect and report on German industry, lately delivered a report at Manchester in which they stated that, compared with these intelligent, skilful and frugal German workmen, the English factory hands were like 'semi-savages'—a rather severe statement."

That we, in the United States, have got to come to the same thing there can be no doubt. All who have had occasion to work in engineering shops, as I have had myself, will have noticed the

large proportion of foreign workers, especially Germans, Swedes, and the like. Now, that process of drawing our skilled mechanics from abroad, cannot go on forever. The time must come when we must produce them ourselves, and the trade school or the manual training school is the school which must produce them. We have begun that work in a small way; the school that Mr. Hamerschlag just described is a very promising example of the kind, and there are others growing up. I dare say that inside of twenty-five years there will hardly be a city, making any pretensions to being up to the times in this country, which will not contain its trade school.

I do not wish to say anything against the trades unions; they have their good points, no doubt. But to my mind one of the weak points in their system is the manner in which they discourage the taking and training of apprentices. Mr. Hamerschlag's illustration of the Horse Shoers' Union is a case in point. Five years is probably not too long a time for any young man to learn a trade properly. Indeed earlier in many of the arts, it was absolutely necessary to require a boy to work five years. But as a matter of fact to-day you cannot get the average boy to stay five years as an apprentice, and bind himself by a written agreement, as was formerly the case. He wants to get at results quicker than that. His refuge, therefore, will be to go to some trade school, like the Auchmuty school here in New York.

As to the establishment of a trade school adapted to the wants of the electrical worker, I do not see why the INSTITUTE cannot take up this subject. I do not mean to say that it should be the founder of such a school, but it can be of great service in starting a movement in that direction. I believe the subject discussed by Mr. Hamerschlag is of such importance that it ought not to be allowed to pass by without some action on the part of this INSTITUTE. Just what action ought to be taken I am not prepared at this moment to state. But I think it well worthy the attention of the Council.

THE CHAIRMAN:—The report to which Mr. Wetzler refers as having been made by a committee of the Manchester Council as the result of a visit to Germany by a commission delegated by it, is a document which has attracted much attention. The report caused a great deal of discussion in English producing centers, as it pointed out that England had not kept pace with Germany in developing trade schools for the training of intelligent labor. The committee visited in Germany particularly the prominent centers of textile industry, and it was evidently much impressed with the opportunities offered to young men in the trade schools, enabling them to become thoroughly familiar with all the branches of the textile industry, and although the report seemed to cast a reflection on the lack of attention which had been given in England to the subject of trade schools, it has had the healthy effect of bringing this matter prominently before the public and

stirring up a discussion of the desirable methods of remedying what is evidently a serious weakness in the development of British industries.

MR. EDWARD P. THOMPSON:—In reference to the point about the education of mechanics in Germany, I had a little experience in connection with the Singer Manufacturing Company, where in my early days of vacation at Stevens, I thought I would like to put myself in that position, and learn something about practical mechanics. I was in the tool room where there were lathes and different kinds of machines for doing work from drawings. I noticed that every man in that place was a German. Every man in that place had been educated as a mechanic in Germany. I could not find one who was educated for that work in America. And they seemed to be interested in me. From curiosity they asked me how much I had to pay to come there to learn how. Of course they could not help but notice how I made the holes too large in the little cranks for the sewing machine, how I broke one or two of the lathes, etc. They wanted to know how much I paid. I told them that the company paid me, and they were very much surprised, because they said they had to pay $100 a year for two or three years to learn how to do these things. I have often thought that the way in which artisans and mechanics are taught in America is a very loose way. The training is gained by accident, by rough experience, and by doing a great deal of harm in places where the learner is first engaged to work. Sometimes, we hear about too many people being educated for electrical engineers and professional men. I think one of the reasons is that many boys are not really fit to become engineers in the future, and really are adapted to become mechanics or artisans, but have had no suitable trade schools to go to. Of course, the next thing is to apply to some technical school with a probability of not even being able to get into the freshmen class. So that I appreciate very much the work that our lecturer is doing and that others are doing in that direction, in forwarding the interests of all kinds of schools for educating those who are to do hand work as distinguished from head work.

MR. HAMERSCHLAG:—I would like to say in relation to the remarks of my predecessor, that one of the most remarkable things I have found in connection with electrical work and the utilization of men, in conversation with them, asking them what they were before they became electrical workers, that it has been the rare exception that I have met a man who claimed that he had ever had any electrical instruction. It has always been the case that he had either been a carpenter or a draughtsman, or worker in some other line. In asking him how he happened to become a member of the electrical fraternity, he would state that there was the field where he got the most money for the least work, to which I replied that I agreed with him, judged by the standard of the New York mechanic. Very frequently I have asked "Why haven't you

done something to improve your knowledge of electricity since you have become a member of the fraternity?" And the reply would be "It is not necessary for me to know anything more than I do know. I can do any work given to me"; always falling down, however, when the work was given to him. It seems to me that it is essential to open the eyes of the journeyman to the fact that to become an electrical artisan he must be just as well trained as to become a tool-maker. As I said in my address, there has been a new form of education to those who are confined to remote districts, who wish to improve themselves, and that is by means of correspondence. How effective that is, the future will show. But in speaking to men connected with the Scranton Correspondence School and the Electrical Engineer Correspondence Institute, I have become convinced that they are doing effective work. Personally, I have not had enough experience to be certain of it. But judging from reports and hearing from men who have engaged under this correspondence instruction, they are certainly receiving some benefit. It now remains for us to establish a sufficient number of institutions such as Germany has, in order to develop these two lines of education, those studying at home, and those that come and take practical lessons. Then we will be able to depend in the future upon excellent mechanics.

THE SECRETARY, [R. W. Pope]:—I had the pleasure of visiting the New York Trade School, a few days ago, and one thought that came up in connection with it was, that while it was very good, there was not enough of it. This school, large as it is, yet so small compared with the city, and so much smaller compared with the country, is turning away young men who are not able to join the classes. This is to my mind, a reflection upon our educational system. I have felt, and I presume many others will agree with me, that one of the principal reasons why more young men are not educated as mechanics is on account of the social prejudice against mechanical work. I would probably have made a pretty fair mechanic in various lines myself, if I had had an early training. My mother thought I ought to be a bookkeeper. I never became one, and what little knowledge I have of bookkeeping I picked up in the railroad and telegraph service. Since this school on the east side, referred to by the speaker, taught the trade of telegraphy, I suppose I can stand accused of being an electrical mechanic in that line, although it is not usually considered a trade. It has always been a source of pleasure to me that I learned telegraphy and that I am able to practice it to-day, and earn my living at it. And right here is where it appears to me that a great mistake is made, that people do not realize that young men when they learn a trade, if they have the necessary qualifications for progress, will either go higher in that line, or their experience may open up another course for them. I have yet to see the man who having first

learned a trade, whatever his position might be in after life, was not proud of being able to do something that showed that he was skilled in some particular line—a skilled craftsman. I was riding through a city one day with a master mason, and he pointed out to me the different houses that he had either built or worked on. I said to him then, that I thought it was a source of gratification to a man through life that he could point to actual works of construction that were, as you may say, monuments to his skill, and I think that such a feeling prevails in every line of mechanical progress. I have a friend, the son of a neighbor of mine, who went through this New York Trade School in the plumbing department, and he is the only boy in the neighborhood out of perhaps half a dozen, who actually learned a trade. He went to this trade school and is considered a skilled workman. One of the astonishing things about it is, when we consider these old-time apprenticeships of five and seven years, that a young man will go to one of these trade schools and master some of the arts in a few months, because he is taught, although I am told that when graduated they are considered merely apprentices. His time is not occupied in sweeping out in the morning, going out after beer, and doing all the rough work in connection with the establishment for a year, or perhaps being kicked around and prevented from learning, rather than aided. Another point in regard to education that I think is worthy of consideration, is that before the boys arrive at the period when they realize the social prejudice against mechanics they should be given in the way of play, if you please, some mechanical work, as a diversion, and to relieve them from brain work, and you would find them glad to devote their time to building water wheels or boats, making their own toys instead of buying them, as is generally the case at present.

If a mechanic is at work in the city, within view of passers-by, you will frequently see a crowd of men and boys watching the operation, as if they enjoyed seeing the mystery of mechanical skill, as much as though they had paid to see a show. In one of those "Notes about town" appearing in a daily paper, it was stated that when a man was seen knocking a hole through a plate-glass window to put in a whirling ventilator, it would draw more people than a dog fight. I spoke of the early training of the boys, giving them these different trades to amuse themselves, you might say, because it has another practical bearing, revealing one of the most difficult problems a parent has to confront in the case of boys, and that is ascertaining what particular trade they are adapted for. Frequently boys come to us who are determined to learn about electricity. I have wondered what this same class of boys did before we had any electric work, and trades were comparatively few. It is difficult to tell what a boy's bent is unless he is a natural mechanic. A boy who has a mechanical turn of mind will generally show it by getting hold of a hammer, and

perhaps doing as my brother did, driving the front door step full of nails. He did not become a carpenter after that but probably would, if he had been trained. His son became quite an efficient carpenter in a manual training class, but is now a traveling dry-goods salesman. If we could find out a little earlier than we do, what a boy is adapted for, and give him a chance to shift, in case he took up the wrong trade, we might save valuable time in the future; when he arrives at years of discretion, and spends four or five years of his valuable time in finding out that he is doing something that he is not fitted for. I made inquiry at the New York Trade School in regard to this point. It is found, that boys take a notion that they want to learn some one trade, and after they get there and try it a little while, they make up their minds they would rather not learn that trade, and change to something else. These are quite important points, and the whole question is a very large one. I was very glad to hear from Mr. Wetzler in regard to the German system, because I think that where we have an example to go by, it is well to profit by it, and there is little doubt that in this respect the German schools are far in advance of any other country.

Mr. Hamerschlag's reference to the fact that electrical workers are frequently drawn from other trades, as carpenters and draughtsmen, reminds me that wiremen were perhaps first generally recruited from the carpenter's trade about 1873, by my brother, Henry W. Pope, at that time General Superintendent of the American District Telegraph Co in this city. He saw that ordinary linemen were not well trained in the matter of doing neat work about buildings and found by experience that for the simple construction of that day it was easier to make a good wireman out of a carpenter, than to teach the existing craftsman how to make a neat job of running wires, especially in exposed work.

Mr. Wetzler:—Mr. Chairman, one has a natural hesitancy about speaking of work with which one is directly connected, and I feel some delicacy in speaking about the subject of correspondence schools which Mr. Hamerschlag adverted to. But there is no question in my mind that one of the great aids to the young apprentice who cannot, by any possibility, attend a school such as Mr. Hamerschlag described to us to-night, is the correspondence school. How many young men that are now growing up in trades are so situated that, even if such a school existed, they could attend it? I should say that the proportion is no greater than that which now exists between the men that are graduates of colleges in the United States, and those that are not; That is, about 1 to 100. For them it appears to me there is no other way of securing that theoretical training—when I say theoretical, I do not mean impractical, but rather the mental training, supplementary to their daily work, which is absolutely necessary to make them intelligent workers. I say this from experience. This experience which is fortified by the testimony of

hundreds of letters, convinces me that the only way in which 99 out of 100 budding electrical workers can be reached to-day is by means of the correspondence schools.

THE CHAIRMAN:—I know that it has done me good to have been here this evening, as it will enable me in the future to reply more satisfactorily to the numerous applications for advice which I receive from fathers and relatives as to what they should do with their boys. It is usually the case that the boy has a mechanical turn of mind; puts up electric bells and burglar alarms about the house, showing a fondness for mechanical pursuits, and each fond father feels that he has in his home a born genius—an Edison, who needs only the opportunity to develop splendid latent talent. I must say that I have often been at a loss as to what counsel to give in such cases. The parents are in most cases unable to send their boys to the higher technical schools, and in pointing out the possibilities which the electrical industries open to young men, they feel satisfied that this is the line which they would have their boy follow. The difficult question immediately follows as to how the boy may obtain a start, and Mr. Hamerschlag's address this evening will go far toward enabling me to satisfactorily meet this question. I hope, however, that it may not have the effect of increasing the great difficulty Mr. Hamerschlag already experiences, in satisfactorily meeting the applications for admission to the trade school.

In regard to the correspondence schools, the question has often been asked me as to their efficiency and the extent to which young men were profiting by the advantages which they offered. The company with which I am connected, employing a number of young men, is of course an excellent field from which to recruit students for the correspondence schools and we had applications from all of them to be allowed to present their respective advantages to our employees. To have permitted their representatives to canvass our employees would have caused serious interference with the regular duties and if allowed during working hours, would have been incompatible with the station rules. At the same time it must be recognized that it is of the first importance to the employer that his employees should be as thoroughly instructed as possible, and it seemed a matter of regret that it was not feasible, without infringing the company's rules, to bring directly to the attention of the men the advantages which these correspondence schools seemed to offer. I therefore took occasion to make inquiries to find out to what extent the employees were informed as to the existence of these schools and the advantages which they offered, and I was surprised to find how well informed the men were on this subject—so well, indeed, that it did not seem necessary to bring the matter specifically to their attention by allowing direct canvassing by the representatives of the several correspondence schools.

MR. HAMERSCHLAG:—I would like to extend a cordial invita-

tion to the members to visit the New York Trade School at any time that they can, and see the work done there in the various trades, and I would like to state that the electrical course is only in session on Monday, Wednesday and Friday nights. On other nights, and during the day, the other classes are in session. If any of the members are sufficiently interested, they will receive a very cordial reception if they merely mention that they are members of the INSTITUTE.

MR. WETZLER:—Before adjourning, I move you, sir, a very hearty vote of thanks to Mr. Hamerschlag for his interesting and important paper this evening. [Seconded.]

THE CHAIRMAN:—It gives me great pleasure to put this motion. It has been moved and seconded that a vote of thanks be extended to Mr. Hamerschlag for his interesting remarks this evening. Those in favor will please say aye; contrary, no. [Carried.]

On motion the meeting was adjourned.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

New York, January 25th, 1899.

The 131st meeting of the INSTITUTE was held this date at 12 West 31st Street, and was called to order by President Kennelly at 8 o'clock P. M.

The Secretary announced that at the meeting of the Executive Committee in the afternoon, the following associate members were elected :

Name.	Address.	Endorsed by
DAGGETT, ROYAL BRADFORD	Electrical Engineer, Electric Storage Battery Co., Marquette Building, Chicago, Ill.	Herbert Lloyd. J. B. Entz. H. H. Wait.
DYER, ERNEST I.	Engineer and Manager of the Engineering Department of the American Trading Co., Box 28 Yokohama, Japan.	C. L. Cory. J. N. LeConte. J. A. Lighthipe.
HILL, GEO. HENRY	Chief Engineer, Elevator Department, Sprague Electric Co., Bloomfield, N. J.; residence, New York City.	F. J. Sprague. E. R. Carichoff. Louis Duncan.
HILL, ERNEST ROWLAND	Electrical Engineer, Westinghouse E. & M. Co., Pittsburg, Pa.	C. F. Scott L. B. Stillwell. Harris J. Ryan.
LYNN, WM. A.	Assistant in Electrical Engineering, University of California Berkeley, Cal.	C. L. Cory. J. N. LeConte. F. V. T. Lee.
SIMPSON, J. MANLEY	Assistant Superintendent, North-Western Grass Twine Co., P. O. Box 2513, St. Paul, Minn.	F. A. C. Perrine. C. A. Carus-Wilson Ralph W. Pope.
THOMPSON, THOS. PERRIN	Electrical Laboratorian, Brooklyn Navy Yard; residence, 217 Cumberland St., Brooklyn, N. Y.	Townsend Wolcott Frederick Bedell. Harris J. Ryan.
THOMPSON, ALFRED J.	Electrical Engineer and Contractor, San Ignacio 50, Havana, Cuba.	Thos. A. Edison. A. E. Kennelly. Gano S. Dunn.
WILSON, ROBERT M.	Student, McGill University; residence, 118 Shuter Street, Montreal, Que.	R. B. Owens. R. A. Ross. Ralph W. Pope.

Total, 9.

THE FOLLOWING ASSOCIATE MEMBERS WERE TRANSFERRED TO MEMBERSHIP.

Approved by Board of Examiners, December 9th, 1898.

PHILANDER BETTS, Electrician U. S. Navy Yard, Washington, D. C.

WINDEN ELWELL GOLDSBOROUGH, Professor of Electrical Engineering, Purdue University, Lafayette, Ind.

THE PRESIDENT:—In introducing the paper of the evening, I have the pleasure to announce that Mr. Greene himself is present and he has, as you know, been spending some months professionally in the navy. We shall look for an interesting paper at his hands upon "Electricity on Board Ship."

A paper presented at the 131st Meeting of the American Institute of Electrical Engineers, New York, January 25th, 1899, President Kennelly in the Chair.

ELECTRICITY ON BOARD SHIP.

BY S. DANA GREENE.

While the title of this paper is intended to cover the applications of electricity aboard ship in the merchant marine, as well as in the navy, I shall confine my remarks principally to the war vessel; for the service requirements of electrical apparatus on the latter are quite as severe as on the former, while the limiting conditions as to weight and space are much more severe. It may be safely assumed therefore that any application which can be made to advantage aboard a man-of-war will be equally advantageous on board a merchantman.

On shore, the advantages of centralizing the manufacture of electric power for industrial purposes in one plant, distributing this power by suitable means to individual consumers, are so well known, and the industry is so well established, that it seems hard to realize the fact that it has all been accomplished in less than twenty years, and that it is less than ten years since it was a difficult matter to interest capital in such undertakings. For several years after the industry was well established ashore, little or nothing was done aboard ship. This was due principally to two causes:

First: Seafaring men are notoriously conservative about introducing new ideas or new apparatus aboard ship, which may prove successful, and which may on the other hand fail in the middle of a long voyage when facilities for repairs are not at hand, and when a break-down may be a very serious matter to the safety of the ship, or the lives of the officers and crew. This conservatism is particularly strong in the British navy, the

greatest in the world, where no machinery is ever introduced when the work can be done as well by hand, and where simplicity is the first requirement for all machinery.

The modern warship is a complex piece of mechanism at best, and I think the established policy of our British cousins to eliminate rigidly all *unnecessary* complications is wise; one that can well be followed by other navies and particularly our own, where there has been a tendency to introduce too many novelties and labor-saving devices, at the expense of simplicity and safety.

Second: Electrical men, while generally unfamiliar with the conditions of sea life, knew nevertheless that three great enemies of electrical apparatus—salt air, moisture and heat—were always present aboard ship, and they feared them.

However, the great advantages of electric lights gradually overcame the sailor's conservatism and the electrician's fears, and lighting plants have been generally installed aboard ship for several years, in spite of numerous troubles at first, both with the apparatus and with the wiring.

The great advances made in the construction of electrical apparatus and the methods of distribution, enable us to say today, and to prove as I shall hope to prove, with a full knowledge of service conditions,—that electrical applications can be made with as little fear and with as great certainty of success aboard ship as they can ashore.

The recent position reported to have been taken by one of the Naval Bureau chiefs that such applications should not be further extended on our war-ships at present, because we did not have the trained men to care for the machinery, is, it seems to me, absolutely untenable. If it is demonstrated that an electric motor is better adapted to drive a deck winch, for example, than a steam or hydraulic or compressed-air motor,—then it should be installed, and the necessary men to operate it can, and should be obtained. If the course suggested by the naval officer referred to, had been followed in our navy for the past fifty years, we would still have sailing vessels, (the frigates and line-of-battle ships of Nelson's day,) and our recent unpleasantness with Spain would have terminated with very different results.

Assuming then as every reasonable man both in and out of the navy does assume, that electrical apparatus *can* be made to work on shipboard, let us examine the conditions of the modern war vessel as we find them, and see where electricity can be ad-

vantageously introduced, having in mind always the necessary requisites; safety, simplicity, efficiency and reliability.

The modern first-class battleship requires about 2000 I. H. P. to drive all the auxiliaries at full load, and the first-class cruiser, about 1200 I. H. P. These auxiliaries, however, are never all in use at the same time using maximum power, and it can be assumed that only about half of these amounts (*i. e.*, 1000 I.H.P. and 600 I. H. P.) will be required at any one time. They are scattered all over the ship, from the anchor hoist forward to the steering engine aft, and from the deck winches and boat cranes on the spar deck to the bilge and fire pumps in the engine and fire rooms, 30 or 40 feet below. Some of them, such as condensers, air, circulating, feed bilge and fire pumps, and fire-room blowers are necessarily located within the engine and boiler room compartments, where the temperatures are always high, and where steam, oil, water and coal-dust are always present in greater or less quantities. Others, located on the spar deck, are exposed to salt water and air and to the varying conditions of sea and weather.

With these scattered locations it is obvious that power, generated at a central point, must be distributed throughout the ship. For this purpose there can be used either steam, hydraulics, compressed air or electricity.. Hydraulics and compressed air not only have a low efficiency of conversion (from steam) but it is difficult to prevent leaks, freezing, bursting of pipes, etc. They have both been tried to a limited extent and both found wanting in service.[1] This leaves steam and electricity as the two remaining systems of distribution from which to choose. As between the two, steam has the following disadvantages:

First: Danger to life. The bursting of a steam pipe, whether in or out of a fight, is a serious matter and likely to disable any of the crew who are in the compartments where the accident occurs. It has been abundantly proven in our civil war, that men will not stand up against steam or hot water, when they will face shot and shell without flinching. Many of our vessels operating in inland waters during that war had several lines of hose coupled to a hot water tank and led out every night to guard against boat attacks. These hose were successful on more than one occasion in repelling boarding parties. While the steam main which leads fore and aft can be run below the protective deck or

1 Benborn's experience with hydraulic turret machinery.

behind the armor belt, vertical branches must run to all auxiliaries on the upper decks and many of these must be used in action. The effect of a steam pipe carrying 100 pounds pressure bursting or being shot away in a compartment where there may be 30 or 40 men, at the guns or passing ammunition, would undoubtedly be to kill or disable every man in the neighborhood and demoralize thoroughly that part of the ship. On the other hand, if a wire is shot away one or more auxiliaries may be disabled but no one is injured; furthermore, the wire presents a much smaller target than a steam pipe and is therefore less liable to injury from shot. It is always a difficult matter, too, to keep steam and exhaust pipes tight and to prevent leaks at the joints and at water-tight bulkheads.

Second: Injurious heating of living quarters. Steam and exhaust pipes must necessarily run to every auxiliary, and some of the latter, such as the ice machine, anchor hoist, steering engine, ventilators, etc., are in the officers' and men's quarters, or the pipes leading to them must pass through these quarters. The heat of the pipes and engines not only makes the quarters uncomfortable but it is impossible to prevent more or less oil and dirt around the auxiliaries. In the tropics the heat is often so great that the officers and men cannot sleep below at all. This was the case on a number of our vessels operating in Cuban waters last summer.

Third: Efficiency. Here the contrast is very striking in favor of electricity, surprisingly so to one who has not seen the actual economy figures of steam auxiliaries. Some data will be presented on this subject later on.

There remain the two important factors of simplicity and reliability to be considered. No one who has had experience with the modern well-designed and well-insulated carbon brush generator or motor, can have any doubt as to its greater simplicity as compared with the steam engine. There are no joints to be kept tight, no nuts or bolts to set up, no packing to renew, no cylinders to cut, and only two self-oiling bearings as compared with a dozen or more oilcups on an engine. In fact it is difficult to imagine a simpler piece of machinery than the modern dynamo. It seems like a return to elementary principles to discuss such a point; and yet many men aboard ship imagine the dynamo a most complicated affair, simply because they know nothing about electricity, and think everything connected with it

is mysterious and complex. This feeling is not confined to seafaring men, as we all know.

The question of reliability is a vital one, for no matter what the advantages with respect to safety, economy and simplicity may be, if the electric auxiliary cannot be relied upon at any and all times to do its work, it is a failure and must be discarded. It must not only be able to work well under normal and favorable conditions, but it must also be able to stand a certain amount of abuse and neglect. Stress of weather and other conditions, particularly during a war, sometimes play havoc with the established routine of a ship, and a sailor's tools must not only be sound; they must be hardy. The normal conditions aboard ship are not favorable to ordinary electrical appafatus, as has been explained, but this simply means that apparatus for such work must be specially designed and built to meet these conditions. The ordinary motor on shore would not last long under a street car; nevertheless thousands of car motors are built and sold every year which run day in and day out with a remarkably low maintenance account. Similarly, apparatus for ship work must be specially insulated, a larger margin of capacity must be allowed, and in exposed places it must be thoroughly enclosed. Several years ago an English manufacturer asked permission to install an electric deck winch on the spar deck of a new cruiser, fitting out at Portsmouth. When the captain who was superintending the fitting out of the ship saw it, he gave orders to have the deck hose turned on the motor for ten minutes, and then to operate the winch. The manufacturer protested and said that the motor was not intended to be abused in this way. "Then take it off the ship," said the captain, "for I cannot guarantee that we will ship no seas during our cruise, and I want that winch ready for service whether we ship seas or not." The captain was quite right, the motor was taken off and a "rough and ready" steam motor substituted.

Experience alone is the final test of reliability and fortunately we have some experience in our own navy on which to rely. During the late war, all of our regular war vessels were fitted with electric lighting plants, and many of the larger ships were supplied as well with certain electric auxiliaries; such as ventilating fans and ammunition hoists. Two of the *Brooklyn's* turrets were controlled by steam motors and two by electric motors. So far as I have been able to learn, from both official and unofficial

sources, all the electrical apparatus on these ships stood the supreme test of battle admirably, and the officers of the *Brooklyn* are enthusiastic over the performance of the electrically controlled turrets. They report that with respect to ease of manipulation and fineness of control, there is no comparison, but rather a contrast. This is high praise from competent authority, for the officers referred to had actual command of the turrets in battle, and their judgment is not only unprejudiced and impartial—it is final and conclusive.

It is hardly necessary to say that electric machinery to be reliable must have reasonable care and attention from men who know something about it. The same is true of *any* machinery and it is bad policy, as well as untrue, to say, as is sometimes said by those who should know better, that an electric motor requires no attention. Cleanliness is very necessary, and may be considered as a first essential to successful operation. It is astonishing to see how little has to be done to an electric motor if it is kept scrupulously clean; but this cleaning must be regular and intelligent. From what has been said, it may safely be affirmed that electric machinery can be made as reliable on shipboard as any other machinery, and with this in mind we can turn to the question of efficiency, including weight of plant and first cost.

There has been very little data published on the performance of ship auxiliaries, but a valuable contribution to the subject appeared in the February (1898) number of the *Journal of the American Society of Naval Engineers*, by P. A. Engineer, W. W. White, U. S. Navy, entitled, "Steam Consumption of the Main and Auxiliary Machinery of the U. S. S. *Minneapolis*." This vessel, as is generally known, is a first-class protected cruiser of about 7500 tons displacement, with three screws (each operated by its own engine) and a trial speed of over 22 knots per hour. She represents the highest type of her class, and is in every way a credit to her designers and builders. She has between thirty and forty steam auxiliaries, and more than 150 separate steam cylinders. Her only electric auxiliaries are the lighting generators and a few small ventilating sets and ammunition hoists. In order to ascertain the steam consumption of her main engines and auxiliaries, Mr. White, who was serving on board the *Minneapolis* at the time, as one of her engineers, made a series of careful observations during a run of the vessel of seven days from Gibraltar to League Island, Philadelphia. Indicator

cards were taken on all auxiliaries fitted for the purpose (31 in number), and the losses from leakage, condensation and radiation were carefully estimated and the water evaporated carefully measured. The results obtained are given in the following tables (marked I. and II.), and they are certainly startling.

An estimate of the average weight of steam used per hour by the machinery in operation is as follows.

TABLE I.

	Total pounds of steam per hour.
Main engines, port and starboard	31,989.8
Condensation from main engine jackets, estimated	750
Condensation in main steam line, estimated	450
[1] Loss of steam from unavoidable leaks, estimated	480.8
Total	33,620.6
AUXILIARIES.	
Main air and circulating pumps	2,641.9
Bilge pumps, (three)	1,291.2
Steering engine, estimated	450
Main feed pump	951.1
Pump for washing decks, ash hoists, galley coppers, shop engine, &c.	240
Dynamo	2,023.3
Flushing pump	275.7
Blower in evaporator room, and combined salt and fresh water pump for distilling plant	46
Steam to evaporators for distilling (average of 1,500 gallons per day)	651
Ship's ventilating blowers, (two after)	549.4
Ship's ventilating blowers, (two forward, 12 hours per day)	274.7
Ice machine	412 4
Miscellaneous (shifting of dynamos, &c.)	80
Condensation in auxiliary steam line, estimated	300
Total, auxiliaries	10,146.7

Hood's Merthyr coal was burned, there being three main double-ended boilers in use.

DIMENSIONS OF EACH BOILER.

Length, feet	20
Diameter, feet and inches	15–9
Furnaces, number (corrugated)	8
Furnaces, diameter (least), inches	40
Furnaces, diameter (greatest), inches	42¼
Length of grates, inches	84

1. Assumed as one-half the total loss of feed water per hour.

Tubes, number	1,268
Tubes, diameter, inches	2¼
Tubes, length between tube sheets, inches	87¼
Tube heating surface, square feet	5,540
Plate heating surface, square feet	861
Total, heating surface, square feet	6,401
Grate surface, square feet	186.7
Ratio G. S. to H. S.	1 to 34.29

RESULTS.

Average boiler pressure, by gauge	142
Coal consumed per hour, pounds	5,215
Coal consumed per hour, per square foot of grate, pounds	9.31
Refuse per hour, pounds	637.5
Percentage of refuse in coal	12.22
Total steam used per hour, all machinery, pounds	43,767.3
Pounds of water vaporized per pound of coal (average temperature of feed 85°)	8.39
Equivalent evaporation per pound of coal from and at 212°	9.89
Percentage of daily coal consumption to run main engines only	76.82
Percentage of daily coal consumption to run auxiliary machinery	22.18

It will be seen that the average weight of steam used by the main engines per hour was 33,620.6 lbs., and by the auxiliaries, 10,146.7 lbs. That is, the auxiliaries consumed nearly 25 per cent. of the total coal used. The main engines consumed an average of 20.83 lbs. of steam per I. H. P. per hour, and the auxiliaries an average of 119 lbs. per I. H. P. per hour (the lowest being 55.06 lbs. and the highest 318.68 lbs. per I. H. P. per hour). An examination of Table II. shows that the steam consumption of the same or similar auxiliaries varied greatly, due doubtless to the varying conditions of packing rings, bearings and valves, and of the load. These results are not exceptional; in fact, they are probably better than the average obtained on most war ships or merchant vessels. The new British cruiser *Powerful* (14,000 tons displacement) is reported to have used 8,300 tons of coal, from England to Hong Kong, of which 3,400 tons (or over 40 per cent.) were required for the auxiliaries.

Under the most favorable conditions the auxiliaries of a large ship probably consume at least 20 per cent. of the total coal and water used. This is more than twice as great as the consumption of a modern central station, and there is no good reason why as good results should not be obtained afloat as ashore.

Let us assume a required central station capacity for a first-class battleship of 1,000 H. P. effective at the motors. The present

TABLE II.

SUMMARY OF TESTS TO DETERMINE STEAM CONSUMPTION OF THE MAIN AND AUXILIARY MACHINERY OF THE U.S.S. *MINNEAPOLIS*

Engine Tested.	Number of test.	Dimen. of engine				Duration of test.	I. H. P. of engine from cards.	Condensed exhaust steam.		Remarks.
		No. steam cyls	Cyl diam Steam.	Cyl diam Water.	Stroke (full.)			Per hour.	Per I. H. P. per hour.	
			ins.	*ins.*	*ins.*	*h. m. s.*		*pounds.*	*pounds.*	
Main starboard engine	1	3	42 / 59 / 92	..	42	53	....	610.85	12,973.	21.237	Average of 7 tests.
Main starboard engine	2	3	42 / 59 / 92	..	42	60	.....	781.39	15,959.	20.431	Average of 8 tests.
Steam cylinder, S. auxiliary condenser	3	1	8	..	12	33.20	5.21.00	1.232	328.07	266.30	Combined air and circ pump
Center circulating pump	4	2	10	*36	6	171.6	3.07.05	18.873	1,039.14	55.06	Approximate power developed on official trial.
Center circulating pump	5	2	10	*36	6	90.0	2 49.30	4.104	310.86	75.74	Slide valve altered Forward cylinder only taking steam.
Center circulating pump	6	2	10	*36	6	89.5	2.11.00	4.039	402.33	99.61	After cylinder only taking steam.
Starboard circulating pump	7	2	10	*36	6	82.1	3.28.20	2.917	252.63	125.28	I.H.P., main engine, 604.
Starboard air pump	8	2	16	31¼	21	16.6	2.58.10	6.543	1,195.70	182.74	I.H.P., main engine, 604.
Center air pump	9	2	16	31¼	21	15.2	3.02.42	25.181	1,969.90	78.23	Pump loaded by opening salt feed valve.
Starboard water-service pump	10	2	7½	4½	10	40.9	2.59.00	1.039	212.92	204.05	Pump used for flushing purposes
Center fire and feed pump	11	2	12	8½	12	12.7	3.30.45	.7851	250.19	318.68	Pump used for flushing purposes.
Center fire and feed pump	12	2	12	8½	12	37.3	1.45.39	6.412	990.23	155.84	Pump used for washing decks.
Center fire and bilge pump	13	2	14	9	12	27.7	2.02.30	2.510	430.43	170.87	Pump used on bilges.
Main fire room feed pump	14	2	12	7⅝	12	11.09	2.23.20	8.828	806.94	91.41	Pump used for feeding steaming boilers.
Main fire room feed pump	15	2	12	7⅝	12	2.61	3.27.00	1.573	382.00	242.85	Pump used for feeding auxiliary boiler.
Forced draft blower engine	16	2	5	..	4	595.3	1.23.35	16.300	1,262.30	77.44	Fire room closed in air-tight.
Ash-hoist engine	17	2	4½	..	4½	....	50.00 / 24.00	.....	.. ..	.....	
Dynamo engine, No. 1	18	2	10½	..	5	408.7	24.00.00	21.873	2,695.60	123.27	Steam pistons water-packed, and bad fit to cylinders; cylinder bores rough and pitted.
Dynamo engine, No. 1	19	2	10½	..	5	424.3	1.15 40	19.598	1,737.1	88.64	New pistons with two cast-iron packing rings in each; in use about 10 days.
						417.0	1.30.10	33.601	2,293.2	68.25	
Dynamo engine, No. 1	20	2	10½	..	5	415.1	24 00.00	23.184	2,023.3	69.33	New pistons with packing rings in cylinders.
Dynamo engine, No. 2	21	2	10½	..	5	391.1	2.48 00	19.1012	2,066.8	108.71	Water-packed pistons; cylinder bores rough.
						388.7	1.29.06	30.354	2,550.7	84.03	
Dynamo engine, No. 2	22	2	10½	..	5	392 0	2.02 00	16.791	1,725.0	102.73	Water packed pistons; cylinder bores rough.
						390.7	1.33.25	26.553	2.250.0	84.74	
Dynamo engine, No. 2	23	2	10½	..	5	425.0	1.10.25	22.923	1,492.7	65.12	New pistons with packing rings; in use about 9 days.
						425.0	26.25	35.837	1,969.2	54.45	
Dynamo engine, No. 3	24	2	10½	..	5	404.3	2.00.00	17.324	1,693.4	97.75	Water-packed pistons; fit cylinders closely. Cylinders in good condition.
						388.3	1.35.76	26.234	2,085.1	79.48	
Dynamo engine, No. 3	25	2	10½	..	5	398.0	2.03.45	18.241	1,488.8	81.62	New pistons with packing rings; in use about 4 days.
						382.5	1.44.50	27.815	2,006.5	72.14	
Dynamo engine, No. 3	26	2	10½	..	5	390.0	12.00.00	20.40	1,962 5	97.92	Water-packed pistons.
Flushing pump	27	1	8	9	12	31.7	3.11.15	1.421	275.7	194.02	
Ventilating blower engine	28	2	4	..	3	277 5	1 59.50	.....	574.65	.....	No indicator motion fitted.
						404.3	52.30		501.83	.....	
Ice machine engine	29	1	7	.	10	73.1	5.12.05	6.024	422.38	70.12	
Workshop engine	30	1	6	..	6	175.1	2.58.00	.....	148.05	.....	No indicator motion fitted.

*Two fans.

Tests Nos. 1, 2, 7, 8 and 14 were made at sea, the others while at anchor.

standard E. M. F. for naval installation is 80 volts, and for the merchant marine about 100 volts. This low voltage was originally adopted on war ships on account of the searchlights, which require 50 volts only, and it was desired to introduce as little dead resistance as possible. At this time no motors were of course in use, and the electric plant was used for lighting exclusively. Such a voltage is, however, entirely unsuited for a 1000 H. P. plant. The weight of the distribution system would not only be excessive, but the size and weight of the generators would be prohibitive. The three-wire system, or a standard of 220 to 250 volts two-wire system should be adopted, using the necessary resistance in the searchlight circuits when they are in service; since they require a relatively small percentage of the total plant capacity, and are not regularly in use, this can be done without undue sacrifice.

The generating plant should consist of several units of the same size, so that parts are interchangeable, each unit consisting of a compound vertical engine driving a pair of generators or a single generator, depending upon whether a three-wire or two-wire system is used. Assuming an efficiency of 82 per cent. for engine and generator, and an average line and motor efficiency of 80 per cent., the total efficiency of the system (between I. H. P. of the generating engines and the effective H. P. of motors) is 65.6 per cent. In other words, to develop 1000 H. P. at the motors will require 1500 I.H P. at the engines, or about 900 K.W. generator capacity. Six sets of 150 K.W. each, with one in reserve, would be required. A good compound engine working at approximately full load (and with six units, those in active service can always be operated at or near full load), will require 20 lbs. of steam per I. H. P. per hour. Assuming a total efficiency of the system of 65.6 per cent., as above, it will require about 30 lbs. of steam per effective H. P. per hour *at the motors*. If we allow 25 per cent. margin for losses due to steam leakage, condensation, mechanical friction of gears, etc., we still have an economy of *37.5 lbs.* per H. P. per hour as against 119 lbs. as shown by the *Minneapolis* test. In this case the auxiliaries tested aggregated 471 H.P. developed, using 56,049 lbs. of water per hour. At 8 lbs. of water evaporated per pound of coal, the coal consumption was 7000 lbs. per hour, or 84 tons per day, assuming that this power was required for 24 hours. If the water consumption had been at the rate of 37.5 lbs. per I. H. P. per hour instead of 119 lbs.,

the coal used per day for these auxiliaries would have been 26.5 tons, a saving of 57.5 tons, or nearly 70 per cent.

It is fair to assume that by the introduction of compound engines and approved mechanical appliances on some of the auxiliaries, the average steam consumption can perhaps be reduced to 75 lbs. per H.P. per hour, but this is still 100 per cent. in excess of that required for the electric drive. Assuming a average daily use of 800 H. P. effective at the auxiliaries on a first-class battleship at sea, this difference in efficiency means a saving in water used of 360 tons per day, and in coal a saving of 45 tons per day. All steam cylinders connect with the condensers, so that the water used by the auxiliaries is not lost but is used over and over again, it being necessary to supply only that lost by leakage in the pipes and condensers. The extra pumping duty is large, however. The coal saved, on the other hand, means that with a given coal endurance (or "steaming radius") a vessel can carry from 10 to 20 per cent. less coal, or expressed in another way, with the same coal capacity, she will have from 10 to 20 per cent. greater steaming radius. The average price paid in the navy for coal (including stations in all parts of the world) is probably at least $7.00 per ton. There is therefore in the case assumed, a direct saving in running expense of $315.00 per day for coal alone. It may be argued that a vessel in port does not use her auxiliaries to the same extent that she does at sea, and that, therefore, the comparisons made are misleading. This may be true as to actual savings in pounds of coal and water, or in dollars and cents, but the percentage differences hold true in any case. Furthermore, a ship is built to keep the sea, and her efficiency and usefulness are measured by her performance at sea, and not when incidentally or accidentally in port. Her weights are distributed or apportioned, and her power, speed and "steaming radius" are designed for *sea conditions*, and it is these conditions alone which should be considered.

The weight and space required for plant are important matters; for a modern steamship, and particularly a war vessel, has every available inch of space and pound of weight carefully allotted; and it is sometimes difficult for the designers to adjust the conflicting elements (which may be equally important) so as to provide for all and still keep within the prescribed limits. The present weight of steam auxiliaries of a first class battleship, assuming a total capacity at full load of 2000 H. P. as before, is

about 200,000 lbs. or 100 tons. If the electric drive is used, we must add the weight of the generating plant. The navy specifications limit this weight at present to one third of a pound per watt of rated capacity. With 1050 K. W. capacity (six units of 150 K. W. for service and one for spare) the weight would be 350,000 lbs. or 175 tons. The electric auxiliaries would weigh about the same as steam, or 100 tons, a total of 275 tons as against 100 tons for steam drive. There would be some saving in the wiring, as against steam and exhaust pipes, so that it may be assumed that the electric plant, with the generating sets described, will weigh between two and one half and three times the steam drive. As an offset, however, we have the saving of 10 to 20% in coal required for a given steaming radius, which in a ship of this class would amount to between 200 and 400 tons. Furthermore, if in the future a satisfactory steam turbine, comparable in economy with the compound engine, is developed for marine work, as now seems probable, the weight of the generating plant will be reduced 40 or 50%, and then the electric drive will compare favorably in this respect with steam, and there will still be the saving in weight of coal required for a given endurance.

The space necessary for plant must be considered as one of the vital parts of the ship, and as such it must be located below the protective deck. At first thought it may be said that it will be difficult to find the necessary space, but it must be remembered that the space required for 200 to 400 tons of coal is available, in addition to the space at present allotted for dynamo room, and these combined will certainly be more than sufficient.

The application of the electric drive to the various ship auxiliaries must be carefully studied in each case. The problems involved, however, are not more difficult than many special applications on shore, nor is there anything about them which a competent electrical engineer, with a proper knowledge of *sea conditions*, is unable to solve. The first cost will undoubtedly be greater than with the steam drive, but the saving in "operating expense," if capitalized, will much more than offset this difference in first cost.

The problem is purely an engineering one, and should be approached in a business-like way. Will the electric drive be equally safe, simple and reliable, and will it be more efficient than the present system of steam drive? This is the question in

a nutshell, and I believe that the figures and data which I have presented enable us to answer it most emphatically in the affirmative. Other nations, particularly England, Germany and France, have already introduced the electric drive extensively on their ships, both in the navy and in the merchant marine; and it is earnestly to be hoped that our own navy, with its magnificent ships, officers and men, of whose record we are so justly proud, will not lag behind in this important respect. Once provide the proper tools, and there need be no fear in this country that the necessary men to handle them properly will not be found.

I have not touched upon some of the minor electrical applications which have been made aboard ship, such as searchlights, range finders, engine room telegraphs, speed and helm indicators, signal sets, telephones, etc. Some of them, such as the signal sets and searchlights, are of considerable importance both from the military standpoint and for navigation purposes, and have stood the test of service admirably. Others, like the range finder and telephones, while of great utility, have not yet demonstrated that they can be relied upon at all times; while others still, may be considered as luxuries (sometimes of doubtful utility) rather than necessities. All of them come within the province of the electrical specialist, rather than the electrical engineer, and have no direct bearing on the main problem discussed in this paper.

APPENDIX.

Since the reading of the above paper, an article has appeared in the March 1899 issue of *Cassier's Magazine*. entitled "The Outlook in Marine Engineering," by Engineer in-Chief George W. Melville U. S. N., from which the following extract is given. It will be seen that his statements confirm those given in the paper with reference to the uneconomical performance of steam auxiliaries aboard ship.

S. D. G.

Schenectady, N. Y.
March 6th, 1899.

AUXILIARIES.

As was stated previously, the problem of the economy of auxiliaries has become a very important one, as the aggregate horsepower of the auxiliaries on a large ship is now considerably more

than the horse-power of the main engines of good-sized vessels of twenty years ago. A paper by P. A. Engr. W. W. White, U. S. N., published last year, set forth the facts in regard to the steam consumption of all the auxiliaries of one of the finest war vessels in the world,—the U. S. triple-screw cruiser *Minneapolis*, —and this is, undoubtedly, a typical case. As shown by that paper, the steam consumption of almost every auxiliary engine on the ship was high, while of some it was enormous.

Various solutions of the problem have been proposed. One is to have a sort of central pump station where a very economical triple-expansion engine would furnish the power and all the pumps would be driven by it.

Another is to make the cylinders of the auxiliary engines, in effect, a part of the intermediate cylinder by having them take their steam from the first receiver, and exhaust into the low-pressure receiver. For merchant steamers which make long runs under absolutely uniform conditions, this would seem to be a very satisfactory solution; but for naval vessels, in which facility for manœuvring is so important, even if this were adopted, it would be necessary to have an arrangement of valves, readily changeable, to throw the pump cylinders out of the circuit and have them take steam from the auxiliary steam pipe and discharge to the condenser.

Another plan is to compound all the engines which have hitherto used steam with only one stage, and that really without expansion at all. This would, undoubtedly, materially increase the economy, but in some cases it would, undoubtedly increase the weight.

Still another solution is the use of electric motors for driving nearly all the auxiliaries. The advantage claimed is that the efficiency of both motors and generators is so high that their combined losses will reduce only slightly the benefit to be derived from supplying the power for the generator from a very economical engine rather than having a small steam-engine to drive each auxiliary.

This last solution is one which has been applied to some extent for such auxiliaries as hoists, winches, and turret-turning gear, and, as far as the working of the auxiliaries is concerned, the result is entirely satisfactory. There are also certain facilities for installation and handling which commend this system above that of small steam-engines located at a considerable distance from the boilers. The problem, however, is a difficult one, and, for its thorough solution, requires more investigation and analysis than many writers have given it.

Even more important than the economical development of power are the items of reliability and adaptation; and the questions of weight, space occupied, and first cost must also be considered. For instance, from many points of view it would seem that the capstan and steering engines afforded examples

where the electric power would have great advantages on the score of facility of installation; yet many strong advocates of motors for other purposes oppose them here on the ground that electric apparatus is not sufficiently reliable for these important places.

Again, from some considerations, motors would seem specially adapted to the forced-draught blowers, but when we reflect how rarely these are used on naval vessels, and that the electric plant to run them (including engines and dynamos) will weigh more than three times as much as steam engines, and probably exceed the cost in a still higher ratio, it becomes nearly certain that it would be far from economical to install motors for this purpose. These illustrations are given to show that it would be unwise to be stampeded into using electric appliances everywhere because they are the best for certain situations.

Mr. George W. Dickie, the talented manager of the Union Iron Works, of San Francisco, has suggested that the solution of the problem could best be determined by taking several ships of absolutely identical design otherwise, and fitting them with different systems of driving the auxiliaries, but having all the auxiliaries of any one driven by one system. The trouble, at present, is that the different methods of driving the auxiliaries are mixed on each ship, so that it is impossible to make an accurate comparison from the results obtained in daily working, on account of the great difficulty of determining the economic performance of each auxiliary separately.

Meanwhile, it should be noted that in all the latest United States naval designs, feed heaters are fitted, through which the auxiliaries can exhaust, thus causing a decided increase of economy; and provision is also made for exhausting (while the main engines are in operation) into one of the receivers. This last practice has prevailed for some time in American ships, and is attended by a considerable saving of coal.

Discussion.

The President:—I feel sure we have all listened with pleasure to Mr. Greene's paper and it is gratifying to learn that electrical appliances have behaved so well on board naval vessels in practical work. I know that you must have a number of questions to ask, and I am sure that Mr. Greene will be glad to answer them.

Mr John W. Lieb, Jr.:—In the comparison of weights I did not understand if the weight of the electric drive included the motors at various points on a ship together with the generating side.

Mr. Greene:—Yes.

Mr. T. Commerford Martin:—Reference was made to the work that was done by means of the motors driving turrets. I think that is one of the most important steps taken in the application of miscellaneous electrical apparatus to our men-of-war. I notice that we have with us this evening Mr. H. Ward Leonard to whom I believe belongs the credit of that advance, and I think we should all appreciate it very much if he could give us a few details with regard to that very important application.

Mr. H. Ward Leonard:—I think that a good many of those present are probably quite familiar with the essential features of the method of control that is used on the turrets, as it is the simplest form of the various modifications of the methods of control that I have described before the Institute. It is, practically speaking, merely this—a motor and a generator, practically identical, (although the speed of them need not be the same, but identical as regards voltage and output) have their armatures connected metallically together, so that, speaking popularly, the armatures are short-circuited upon each other. The field of the motor is fully excited at all times, and the generator has in its field the winding which is similar to the shunt winding of an ordinary generator, a field rheostat, which not only enables you to vary the current over a very wide range that passes around the field of the generator, but permits you to reverse that current. The generator armature being driven at all times at full speed, and in this field which can be varied from zero intensity to full intensity in either direction, the field current supplied being from a separate course of constant electromotive force such as the lighting circuit, you will see that a very ready method is offered of obtaining at the brushes of the generator any voltage, from zero to the maximum voltage, and this voltage in either direction. Since the field of the motor is constant, any reversal of the voltage of the generator will cause the current to flow in the reverse direction in the armature circuit, and consequently cause a reversal of the motor armature. The point which is perhaps of the greatest importance to make clear, is the very perfect control which you obtain under such conditions due to the fact

that the two armatures are, as far as voltage is concerned, electrically locked together. It is impossible that the voltage upon the terminals of the motor armature and the voltage upon the terminals of the generator armature should differ, except by the drop in the very low resistance metallic circuit formed by the two armatures short-circuited together. Consequently, it is quite different in this regard from any case in which a large percentage of drop is occasioned by the passage of the current through some rheostatic resistance. We can with this arrangement say with positiveness that if we produce a certain definite field in the generator, which means if we place our rheostat at a certain definite contact, the voltage of that generator will be fixed, and hence the voltage supplied to the motor armature in a constant field will be fixed, since the speed of the motor will be in proportion to its counter-electromotive force, and therefore practically in proportion to the voltage of the generator in the system. The speed of the motor becomes definitely fixed, and there will be a definite speed for each position of the generator field rheostat, and this speed will not be dependent, as would be the case with the rheostat controlled motor, upon the torque of the motor, but on the contrary will be practically independent of the torque. Since the motor field is entirely independent of the armature current it is possible to obtain a speed which under all conditions of load will be exact and precise, and hence any desired speed over the entire range from the slowest motion to the full speed, can be readily maintained. Another point which is of great importance and is peculiar to this arrangement is, that it is quite easy to control the speed not only in accelerating the speed, or maintaining the speed, but also in retarding the speed or stopping the motor, as the motor will instantly become a generator in case we lower the field of the generator so that the voltage of the generator would tend to fall below that of the motor. In the case of the application in question, where there is a very large weight, if it is in motion at a certain speed and it is desired to reduce that speed or bring the motor to rest, a very rapid but extremely gradual retardation of the load is effected by the insertion of resistance in the generator field which drops the voltage of the generator below that of the motor. The motor consequently becomes a generator and sends a large current around the armature circuit in the reverse direction, thus tending to increase the speed of the prime machine, formerly the generator, now acting as a motor, which in turn delivers that energy to the original source as useful energy. One point that I think perhaps may not be evident, but is of importance, is that in the acceleration or retardation of a large mass, the very best results can be obtained when the force which is going to cause the acceleration or the retardation, is produced in such a manner that the energy is in proportion to the square of the velocity. The action of a ship coming to rest in the water, as we all know,

is extremely smooth, and when the ship does come to rest in such a way we do not feel any such effect as tending to fall forward or backward; our motion is retarded in such a manner as to be entirely natural, and the action of the water opposing the motion of the ship and comparable to the torque, is such as to be proportional to the square of the velocity. In the electric circuit as it exists in the armatures, joining the generator and motor in question, the speed is proportional to the volts, and the relation thus obtained enables one to get an acceleration and a retardation which is comparable to that which is met with in the case I have described, and it is impossible to secure by the ordinary methods any such smoothness of stop. As I think has been very clearly brought out in a great many papers in connection with the braking of trains, the torque of a mechanical brake is greatest at the time when the speed is lowest; whereas for proper retardation the braking effect should be very much greater at the time when the speed, and consequently the momentum of the load, is highest, and the braking effect should taper off rapidly as we come towards rest, which is exactly the reverse of the conditions which are met in a mechanical brake of the ordinary kind. This is familiarly known to us from the fact that a man on the old form of street car could, when he was bringing the car to rest, jam his brake strongly while the car was going pretty fast; but in order so make a smooth stop must necessarily greatly relieve the brake as he came toward rest, or else the stop would be very disagreeable.

I am not familiar with the exact details of the arrangement for the *Brooklyn*. The installation was made by the General Electric Company, who are licensees under my patents, and I never have myself seen the installation on the ship, but it is practically as I have described as regards the electrical conditions. Of course, it is a great source of pleasure to me to find that the system is working so successfully, and while it of course does not surprise me, I think the perfect operation of the system will probably surprise a good many of the people who have thought in the past that the system could not possibly have the features of simplicity and perfection of control, both in acceleration, retardation and reversal, that I had claimed for it. As perhaps a good many may remember, it was thought by those who criticized the system that necessarily difficulties and insuperable difficulties would be met, as regards the sparking of the generator; but in a well designed generator of modern type no difficulty of this character is met with. Quite a number of members who have discussed this system before the INSTITUTE in the past have thought that while it might have some points of advantage, that it practically was equivalent in its effects to a rheostat control, except that the power that was wasted in a rheostat was saved, and also that a good many, and perhaps all of the effects of the system could be accomplished

by means of a series-motor, or perhaps some form of compound motor, but this is not correct, as there are peculiar effects in this system which are not met with where anything equivalent to resistance is introduced in the armature circuit, or where any material disturbance occurs in the field of the motor that is being controlled.

I am sorry to note from the most recent reports that the decision of the parties in control of naval affairs seems to be unfavorable, as regards the use of electric motors except for the turrets; but it seems to me that with such evidence as is being forced upon their attention by papers such as this, that in a very short time the electric motor, with its advantages manifest to all of us, will take the place of the steam motors for the auxiliaries.

One point that has been touched upon by Mr. Greene but perhaps not emphasized as much as it might be, is the fact that there is a very wide diversity of efficiencies in engines of the same duty and the same size, and this is a difficulty which it seems to me is always inherent in steam engines; there is not the same possibility of ready measurement of the power that they are consuming, and there is always the probability that some portion of the engine may be packed too tight, or that there may be some cutting, and we all know that it is reasonable to expect, if we have two 5-horse power motors, for example, of the same make operating under the same kind of duty, that their performance would be uniform and their efficiency would be practically identical, and that if there were by any chance, conditions that made the efficiency of one poor compared with the other, that it would be a matter of the simplest kind to make a measurement in a few moments that would show by the ampere-meter conclusively the difficulty that existed and immediately locate it, and thus save a waste of power which would be likely on the other hand, to go on indefinitely in steam engines. I thank you very much for your attention.

PROF. ELIHU THOMSON:—I happened to make a trip about two or three months ago to Washington for the express purpose of convincing the department, as far as I was able to, that electricity was the only thing to use on shipboard, in place of these numerous steam plants. As I thoroughly believed that to be the case, I made the best plea I could of course. I found, however, that in one of the departments especially, there seemed to be an idea that we should move slowly; do one thing at a time and test what we had done before leaping in the dark. That might be a rational estimate of the situation coming from one who probably had not looked into the comparison between these various sources of power and electrical power. However, I am perfectly satisfied that the time is short when it must come about that an electric equipment, on account of its numerous advantages, will be adopted for practically all of this distribution of power around

a ship, just as it is being adopted for the distribution about a large city. The reasons are even more cogent in the case of a ship where the coal consumption is a vital factor. One cannot look at the tables presented by Mr. Greene, without seeing the enormous coal consumption of some of those small powers, and yet I know it also as an experimental fact, that engines as small as four horse power can be made to develop a brake horse power, not indicated—on about 20 pounds of water per horse power hour; that engines probably of larger capacity can be made to go very much below this, and those engines will be simple, non-condensing engines, uncompounded. Now I make that statement advisedly because I have been experimenting for a year in that direction. Engines of this kind can be turned out in any machine shop without any particular difficulty, being as easy to make as any simple engine. I find curiously enough that after doing a considerable amount of work in this direction, M. Serpollet of Paris has recently published a statement concerning a steam engine as applied to horseless vehicle work, and I find further that his engine is about the same as mine. This goes to show that we have been thinking pretty much in the same groove. I need make no secret as to what the engine is, because M. Serpollet has published it, although of course our patents are pending. But it is so simple that it is astonishing that something of the kind has not been used or at least experimented with before. If it takes over twenty pounds per horse power—and *indicated* horse power as noted in that table—(referring to one of Mr. Greene's tables) in the main starboard engine, and we can do as well with a non-condensing simple engine of four horse power, we have certainly done something worth while. My reasoning was this: that the gas engine is an efficient engine and that I must run my steam engine on the same principle of the gas engine. In other words, I must imitate the cycle of the gas engine in steam, and then I would get high efficiency, with other advantages. If I represent an ordinary steam cylinder as an open-ended cylinder in Fig. 1, and put a piston P in that cylinder, well packed by rings, and either use a straight piston rod and guides in the ordinary way, or the connecting rod R jointed to the piston, we have the type of engine as it stands. Now instead of reversing the motion of our steam as it enters back of the piston and throwing it back to the heated surfaces in exhausting, we are careful never to throw it back, but always let it go forward. We make an exhaust consisting of a number of holes uncovered by the piston at the extreme outward portion of its stroke as at E. The piston is moving slowly when it is out here near E and there is plenty of time, if the holes are made around the piston, to discharge all the steam. In order to use the steam superheated so as not to burn the valves or injure the engine, and we use somewhat superheated steam, or quite dry steam, we simply have here a poppet valve V which is raised by

proper valve mechanism in time with the rotations of the crank. The steam supply pipe from the steam generator is at s. Now let us see what we can get in this engine. In the first place let us suppose the engine cylinder has been exhausted of steam at E to atmospheric pressure. If we construct an indicator diagram, Fig. 2, calling base line atmospheric pressure, we reach the end of our stroke at *e*. Instead of letting the piston go all the way up to the end of the cylinder we can allow a clearance space which represents the clearance space in a gas engine. We can thus allow a certain compression; and the compression can nearly equal the boiler pressure, or it may fall below it. This seems to make but a slight difference. We have, therefore, adiabatic

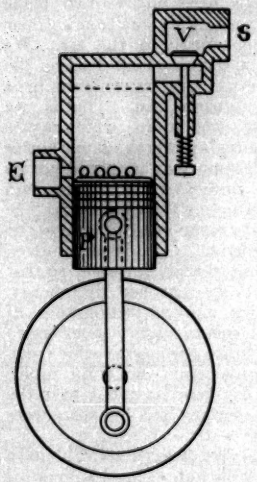

Fig. 1.

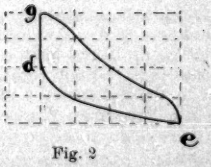

Fig. 2

compression with a slight heating during the compression line along *e d*, Fig. 2, because the steam left in the cylinder is being driven up towards hot surfaces, those that have been heated by the live steam. Then we have valve v opened suddenly, and pressure rises to boiler pressure *g*. The valve v stays open but a very short time, and expansion takes place from *g* to *e*. The diagram resembles a gas engine diagram. What is left in the cylinder is again driven up and compressed. Now what is the result? There is a temperature gradient from one end of the cylinder to the other. The steam always coming in hot, cools off by expansion; by the time it gets to E it is ready to go out. It sweeps out all water of condensation—explodes it out or blows it out,

and what steam is left in the cylinder is driven back on hot surfaces, dried, superheated; the poppet valve opens and makes as it were an explosion of steam; remains open but a small time and expansion brings the pressure down again and so on. The engine with four cylinders, $2\frac{1}{2}''$ in diameter, $3''$ stroke has given the result of $20\frac{1}{2}$ pounds water per horse power hour.

MR. GREENE:—What steam pressure?

PROF. THOMSON:—160 pounds, anywhere between 160 and 200 pounds. No doubt it can be made to run with higher pressures. There is no question about that. It could be run on 300 pounds easily enough. The result of it would be that if we needed engines to equip boats very rapidly in case of a war we could turn such engines out in a very short time. We need not wait to make elaborate compound condensing engines. This small engine does not condense at all; the escape is outwardly to the air. We made careful brake tests, driving a dynamo and loading the dynamo, and against the results of test is the transmission by a chain and the bearing on which the dynamo ran. That is, we really ought to allow about five per cent more, which would bring the steam down to about $19\frac{1}{2}$ pounds per brake horse power hour. With a large engine I see no reason why it should not go down to something like 15 or 16. Surely we ought to gain something with increase of size. But notice the conditions. The conditions are such that there is no re-traversing of passages, no re-traversing of even the cylinder portion. The steam enters, goes forward and out, and it is running steadily forward, so that we do not have any of those inter-actions that use up energy. We have a temperature gradient from one end to the other of steam cylinder. We use superheated steam, highly superheated if we please, because the engine is like the gas engine which can use flame. We have run it at all degrees from moderate superheating up to red heat. The engine has been operated with the steam pipe red hot right up to the engine, but our tests were made when it was at a moderate superheat.

MR. TOWNSEND WOLCOTT:—I would like to ask Prof. Thomson if there is anything equivalent to variable cut-off in this type of engine.

PROF. THOMSON:—Yes; we have a variable cut-off, although we usually run it at full load with a very small time for feeding steam. In starting, we of course give steam during a good portion of the stroke of each of the four cylinders. In order to get continuous torque in this case, we give it for about two-thirds of the stroke.

MR. WOLCOTT:—One of the chief drawbacks to the ordinary gas engine is that there is very little speed regulation, and then when running too fast a stroke is lost and it don't take gas on that stroke.

PROF. THOMSON:—There is no difficulty whatever in this case. We have in fact a variable cut-off arrangement whereby we can

give a little more or a little less steam or run on compression alone for a few revolutions.

LIEUT. WALLING:—I have listened with much pleasure to the instructive paper read before the INSTITUTE this evening, and being here in the capacity of a listener, without expectation of taking any part in the discussion, my remarks on the subject of the lecturer's paper, a subject with which I have been intimately associated for the past two years, must be more brief than I should desire. In all the discussions which come up regarding electrical installations on board ship there are a great many things to be considered that I do not think are understood in commercial life, for electric appliances of all kinds have their severest tests in naval installation.

In regard to the *Minneapolis* and the use of steam and coal for auxiliaries; we have made several tests on board ships on dynamo engines for water consumption. I am not aware that it is known to the INSTITUTE but we have gone through a long series of types of engines each tending toward better efficiency and are now using the tandem compound. We are now getting an efficiency of about 21 pounds per indicated horse-power and about 30 to 32 per kilowatt hour. We started out with engines that I think must have, on original tests, given about 65 pounds per indicated horse-power, and have later come down to about 48 on the improved types. The *Minneapolis* had pistons that were not packed and wore badly. They were of rather soft material. The steam short-circuited from one side of the piston to the other. In a similar type of engine, almost the same type, used on the *Marblehead*, there was 125 per cent. increase in a period of two years. You cannot get good coal economy with that kind of an engine. We repaired the *Marblehead's* engines, packed the pistons, and have never had any like trouble since. We took the matter up then with the company which made the engines. They have since packed pistons and their engines have done very well.

The case of the *Marblehead's* engines has been repeated in a number of ships and, until I heard the data given in this paper, I was not aware that the economy of other auxiliaries had ever been effectually tested.

The installation of electrical appliances for working all auxiliaries on board ship will, I think, be very general within the next two years. There are, however, two types which we will be rather slow in changing from steam drive, namely, the anchor gear-windlass or capstan—and the steering gear. It is still a question as to the availability of motors for their use. Motors will answer for most of the uses in commercial life; but for anchor use, when a ship is pitching badly in a heavy sea and her anchor must be weighed, the motor may or may not be reliable, and we cannot take the chance that it may not. It is mainly a question of application. With steering gear a similar condition obtains from the "kicking" of the helm in heavy weather.

The question of voltage has been mainly one of insulation and loss in searchlight rheostats: the commercial practice of placing two arc lights in series having some undesirable features on board ship, mechanically, and in the intended use of the searchlight itself.

Ship grounds, whether the wire be in molding or conduit, are frequent and troublesome and therefore low voltage is desirable.

We are using $\frac{1}{64}$ pure rubber and $\frac{3}{32}$ vulcanized, in addition to tape and braid, on our branch conductors of No. 14 B. and S. wire and still have difficulties with insulation even at almost double the Underwriters' specifications. It is particularly the case with bell wiring, which, though not so well insulated, continually requires repair. The interior communication system of the *New York* is now badly grounded after a carefully covered-in installation by the Cramps.

It is a curious fact that low voltage is a characteristic of all navies. We use 80 volts and it has been adopted by Great Britain. In other navies 65 volts is the more common pressure. While it would be perhaps more economical to use 250 volts, in view of increased motor use and commercial rating of machines, I hardly think it will ever be adopted, although we are now installing the new battle ships *Kentucky* and *Kearsage* at 160 volts, on the three-wire system, preserving 80 volts at the lamps and connecting the motors across the outer mains.

As for conservatism in the naval service, I think it will be found that apparent delay in what is regarded as progress in electrical work is mainly attributable to a desire for the best obtainable product and standardizing it when found. In the vexed question of wire we have endeavored to introduce that which would be sound and acceptable as the best construction. We are now endeavoring to get a standard incandescent lamp and legalize candle power on the lines of good construction and careful test. Government appliances should in my opinion be a standard of reference, from up-to-date scientific requirements, and, to ensure accuracy, the standard result must be obtained carefully, which necessitates time and experiment; and we should be slow to adopt apparatus which will subject us to well-grounded criticism on faults of specification. This must apply particularly to the adaptation of electricity to power when we must take the conditions of the ship where weight and space and vibration, together with insulation and water tightness, are no mean or lightly-to-be considered factors as regards the device and construction.

CAPT. JOHN MILLIS:—Although belonging to a branch of the service whose duties afloat are quite limited, I am much interested in this subject in a general way. There were three points that occurred to me concerning which I think Commander Greene can enlighten us. I understand that all these installations on board ship are direct current installations. Of course

we understand the limitations as to distances of transmission on board of a man-of-war, but it seems to me just possible that, in view of the peculiar conditions, it might be advantageous to make some applications of the alternating current system, or of the polyphase system on shipboard, and I should be very glad to have some points with reference to this suggestion.

As has already been brought out I understand that the questions involved are very largely in respect to getting very heavy weights in motion and of stopping them. That is, those considerations are of great importance in the handling of turrets, in ammunition hoists, in the steering gear to a certain extent, and perhaps in other applications with which I am not familiar. There is also the question of different voltages and of transformations, so that it seems to me possible that there might be some field for the alternating or polyphase system, although of course, in a form quite different from conditions ordinarily met with in commercial applications.

The second question is of a military nature and one which most of the gentlemen present are perhaps not very much interested in, but I recall seeing some reference to the use of searchlights at Santiago. I understand that in the operations there, the defensive use of searchlights was demonstrated, and it has even been said that Admiral Cervera's fleet did not come out at night on account of the confusion that it was subjected to by the searchlights of our own vessels lying outside. If that is correct, it will have an important bearing on our shore defenses, and the question arises as to whether it would not be advisable to install a large number of searchlights in these defenses, not only for the purpose of discovering the enemy—which is the principal object of the searchlight as it is now employed—but also for the special purpose of confusing him after he has been discovered.

The third point is in reference to the personnel on shipboard. We find in the military service a considerable difficulty in this matter. Unfortunately in time of peace men are not induced to enlist from patriotic considerations alone, and other considerations are not always specially inviting; and the line of promotion is not all that might be desired. The commercial demands for men who are skilled in a mechanical way or in an electrical way, are generally more inviting than anything that the military service offers, and the skill of the enlisted man is not always of the highest order. Possibly there is in the navy some more enlarged system of promotion, a larger number of non-commissioned or warrant positions, offering greater inducements for the enlisted men, which Commander Greene could enlighten us about. These considerations have a very important bearing on the questions which we are now dealing with in the military service.

MR. H. L. HOLBROW.—In such an installation as Mr. Greene speaks of, the electric plant becomes a most vital portion of the

ship, and in the navy where the liability to damage or destruction is great, it might be advisable to duplicate the plant, each portion being in a distant part of the ship. This would not be necessary in the merchant service, however. Mr. Greene's estimate includes six machines. Should a division of the plant be decided upon, it would be good practice to place four machines in each portion. This would increase the weight by one-third. A rather undesirable feature.

Many of the gentlemen here this evening are perhaps not familiar with the personnel of the navy, and consequently do not know the kind of men that would be placed in charge of such a plant. I served in the navy as an electrician during the summer, and of course was brought into contact with many of these men. The apparatus aboard ship is managed by the gunners mates, who hold ratings as chief, first or second class petty officers, and receive salaries ranging from 35 to 55 dollars per month. They are trained for their work at the gunnery school, where I believe, they spend one year in studying the construction and handling of guns, and the management of dynamos. The greater part of this time is devoted to gunnery, so that very little can be devoted to the electrical portion of their work. Should one of these large plants be immediately installed, it would probably suffer for the want of trained management. However, as these changes will in my estimation be a matter of gradual development, the government will be able to train and supply men for this particular work as the occasion requires.

Mr. T. Commerford Martin:—There are various points in Lieut.-Commander Greene's paper which, it seems to me should not pass without some comment and possibly explanation. I was somewhat struck with the reference which Mr. Greene made to the inefficiency of telephonic service on board men-of-war. I must confess that that intimation comes to me somewhat in the nature of a surprise, just as the later intimation did of the failure of electric bells on board ship. It may possibly be due to the fact that this expert work in bell-wiring and telephony was done by the Cramps. I had not heard of them previously as particularly expert in that direction, as they are in others, and do not remember at any time having found it within my province to commend them for their skill in electrical work. It is possible that if this work were left to those who know something of bell wiring as such—I mean as an art, not merely as an industry to be accomplished at the lowest price possible that the work can be done for, and if the telephonic work were left in the hands of those who are competent to handle telephonic apparatus,—there might be better reports. It is possible, however, that Mr. Greene has been misinformed as to telephonic work on board ship, and this possibility is somewhat borne in upon me by a little experience of my own recently in pursuing an inquiry with regard to electric range finders. It was announced somewhat early in the

war, and soon after one or two of the actions or engagements had taken place, that the electric range finders were no good, that they had collapsed, they had failed, could not be worked. I immediately started out to get a little information upon that subject. It was somewhat difficult at that stage of the game; all those who had anything to do with it being still too busy fighting, and not yet writing magazine articles on the subject. I did all I could however, to find out whatever was possible from our fleet in Cuban waters, but not eliciting any information in that quarter, I wrote out to Manila, to my friend Bradley Fiske, told him what I had heard, and expressed, as I naturally would under those circumstances, my doubts as to the accuracy of the information. His heart warmed toward me, and he wrote back very fully on the subject, and said that so far as he had heard he did not know just where those things had been tried, and would like to know, and asked me to go on and investigate further. I did so until at last I landed somewhere in the Navy Department, and there is at my office a statement from one of the bureaus—I will not attempt to distinguish it—stating that as far as it knows, not a single electrical range finder was in service during the late war. Hence, it seems to me that the slight criticism which Mr. Greene conveys by that remark in his paper is hardly justifiable under the circumstances, and I venture to believe that if the inquiry could be pursued right down to the closest detail, we would find that telephones also are a pretty good thing on board ship, and that all that is needed is that the wiring shall be done expertly and properly, and that the wires, the bell wires for example, should not merely have the insulation which our friend Lieutenant Walling has described, but might possibly go through tubes which would more or less protect them from the action of salt water and sea air. The whole thing simmers down to the difficulty the navy has in retaining the men who have mastered the details of electrical appliances. They are not willing to stay in the service. If the navy could retain those men I think we should have great unanimity in the navy as to the desirability of electrical apparatus. But the trouble of it is the electrical men won't stay in the navy. We have a distinguished instance here on the platform to-night, and as long as the temptations for talent and ability are such as the larger field offers, I am sure nobody can blame them. We are all glad to have them on shore, although I did hear a man the other day complain that the naval men were getting all the large jobs, even down to the consultation of the Third Avenue Railroad.

One of the events of the late war in connection with the work of electrical apparatus, struck me particularly, and it is a field in which I think there is certainly room for improvement. After Admiral Dewey had sailed into Manila Bay and had presented Spain with the largest submarine fleet in existence, the cable being cut, we were absolutely at a loss; we could not com-

municate with that part of the world at all. Now, a navy that can cut a cable, certainly if it is worthy of the name, should have the ability to repair a cable when it is cut. I am sure that we must all have read with feelings of despair and indignation some of the proceedings off the coast of Cuba, when men-of-war's boats and launches and even larger ships, lay there exposed to the fire of the enemy which even once or twice did prove deadly and were sawing and see-sawing and hacking and chopping at those poor, unfortunate cables and trying to cut them; whereas one or two old cable men under the guidance of such an expert as we have on the platform in our President would probably have disposed of the job in a few minutes. It seems to me if we are going in for a navy, and if we are going in for expansion, the very first thing that our navy will have to do will be to provide itself with an equipment of that character. This little fact has very much impressed itself upon me in the last week when the navy decided that in order to protect our interests in the Philippines it would be necessary to connect the various islands together. As far as I am aware there is not a single man in the United States navy to-day who is in anywise competent to conduct those operations, and the result is that we have to go to England, and I understand that English talent has already been hired by our navy to go out to Manila and do that work. I am glad to know that we are buying the cable in this country, but I believe that all the auxiliary apparatus, without exception, is being ordered by our navy to-day from England. Personally I am one who rejoices from the bottom of his heart over the Anglo American alliance, and like to see that we can depend on our good English friends for assistance of that character. But I should feel far more delighted if I knew that we could depend on our own resources for work of that kind in this country, and that such resources were at command in the service of our navy.

Mr. John W. Lieb, Jr.:—I think the figures which the speaker of the evening has presented to us, are of very great importance to central station men, particularly as the problems which they have to meet in the mechanical conduct of the stations are not altogether dissimilar to those met on board ship. The problem of electrically driven auxiliaries versus steam driven auxiliaries is of quite as pressing importance from the central station point of view as it is on board ship, and I think it would possibly cover a point not previously referred to, if one or more features connected with the difficulties of auxiliary drive by electricity were pointed out. In the tabulation we have before us, one advantage of steam drive certainly as applied to central station practice, probably also as applied to marine practice, does not appear. If from a central station, assuming it to be a condensing station with electrically driven auxiliaries, air in circulating pumps driven by electric motors, boiler feed pumps driven by electric motors, drip water pumps driven by electric

motors, an important problem arises—the heating of the feed water with the exhaust steam, and boiler feed pumps driven by steam. Where condensing apparatus is used, auxiliary feed water-heaters are available which are important in enabling the exhaust from the auxiliary steam driven apparatus to be utilized in heating the feed water. This is an important matter for every station, and I presume it would be the same case somewhere on board ship. Exhaust steam which returns to the boiler and from which part of the heat units in the steam used for steam drive, is not obtained from such sources; it must be provided for in another manner and at a considerable cost. This saving has not been mentioned as an element of advantage in the steam drive, and should certainly be brought forward in a full and fair presentation of both sides of the question. I would like to add one more point, and that is the point of flexibility of control. In such important elements as turret turning, the installation of systems, such as Mr. Leonard has described, become important, and the extra apparatus required and the additional expense, is warranted by the importance of the apparatus to be controlled, and also by the fact that units are small in number. But when it comes to controlling a number of pumps, electrically driven boiler feed pumps, air and circulating pumps, the difficulty of getting a sufficiently wide range by rheostat control or the limited control given by field rheostat becomes of very considerable importance; and where electric drive is reserved for boiler feed purposes, it is often necessary to run the pumps driven electrically at practically constant speed, and do the regulation by a steam driven pump; or when the electric unit becomes too large to handle the power plant at full load, it is necessary to resort to the steam driven pump to get a sufficiently wide range of regulation and control.

I was very much interested in the presentation by Prof. Thomson of his experiments in connection with the reduction of steam consumption in small steam motors. It is a subject which is extremely interesting to me, and while to discuss it thoroughly would lead me too far afield, I just wish to refer to certain observations which I had the opportunity of making last summer while on a trip abroad. The question of the use of superheated steam has passed from the stage of theoretic consideration to the stage of application in practice. Among the most prominent advocates in the use of superheated steam is Prof. Schmidt. The results that he has already obtained are surprising. I have seen tests conducted by German experts on similar engines of 50 and 60 horse power where the steam consumption is below ten pounds. Of course, in handling steam superheated 500° or 600° Fahr., new problems arise, which I will not undertake to discuss, but simply point out the novelty to some extent at least, we might call it, the novelty of the use of poppet valves for the steam admission, the point referred to by Prof. Thomson in his

discussion. No doubt the use of superheated steam will be a matter which we will hear much of in the very near future, as indicated by the enormous progress which has been made in its application abroad.

Capt. Millis:—If I may be pardoned for one word further—I think we are all ready to concede that the United States navy does not need any defense at this time, but the remarks which the gentleman made on the subject of cable cutting recalled to my mind the fact that I saw a section of one of those cables that were cut on the south shore of Cuba during the late war. The shore there is extremely bold, and great depths are found close into shore. The section I refer to was of shore cable. It was about 3¼ inches perhaps in diameter. It had a double armor of steel wires. The outside wires were nearly as thick through as one's little finger; and, although I am not prepared to state that the cut which I saw was the cut which they made, it is natural to suppose that they made the shortest and cleanest cut it was possible to make under the circumstances. I understand they grappled and raised that cable from a small boat. They were under fire, several of the men were wounded, and I think one or more were killed while they were hacking and sawing at this cable. They finally succeeded in getting it separated. I have had considerable experience in handling submarine cables of a good deal smaller size than that, but I never attempted to cut one under the fire of Mauser bullets, and I do not think that the most skilled civilian electrician not accustomed to military discipline could have done any better than those men under the circumstances.

With regard to the repair of the cable running to Manila, it is a military principle—I suppose also a naval principle—that means of communication with headquarters in case of operations of that kind are sometimes very necessary, and very valuable and very desirable. Under other circumstances it may be better to have the cable thoroughly and effectually cut.

Mr. T. Commerford Martin:—I hardly think that it needs any avowal from me that I would be the last, or certainly among the last, to reflect for one single instant in thought or word upon the glorious valor of the men who put themselves under fire to go through such an operation as that, and I know that had our friend Capt. Millis himself been there the operation would have been just as successful as it could be with the resources and experience which he has at his command. At the same time I would like to say that I have heard criticism and comment made both by officers in the navy and by those who are familiar with cable operations in the Atlantic upon the subject of that work, and they have united in saying that it was an unnecessary and needlessly long exposure of the men who were unfamiliar with such work, and which would have been much better done had cable maps and proper resources and trained men been at the

disposal of the officers commanding the squadron at that time. That was at least the point that I wished to make. I would like to emphasize what I have just stated in regard to electricity in the navy, and the fact that the men who know something about it should be in the navy, by saying I do believe that the remedy will come if one of the measures now before Congress happens to go through—that which looks to the unification of the line and the engineer officers. I think that is a step which we all look forward to with a great deal of hope, and which we trust will very shortly be accomplished.

MR. JOSEPH BIJUR:—There is one other point in connection with high voltage on board ship to which I should like to refer, that is, regarding the use of searchlights. As a rule a voltage is well adapted to searchlight operation when there is a drop of 25 to 35 volts between the generator and the arc. The arc is peculiar in being in unstable equilibrium, and its action is so rapid that its resistance either increases or decreases enormously before any mechanism can adjust itself to take care of it. To overcome this difficulty, it is customary to insert an external resistance between the generator and the carbon terminal. This acts as an automatic regulator, without any time element. The moment the resistance of the arc becomes less, owing to some increase of the current and consequently of the cross-section of the arc, the voltage at the carbon terminals falls, because of the increased drop in the external resistance, and the current comes back to normal value. If, on the other hand, the resistance of the arc tends to rise because its cross-section was diminished by some decrease in the current, the voltage across the carbons rises correspondingly on account of less drop in the external resistance, and the arc re-establishes itself.

When you have a drop of 25 volts between generator and arc you have about the right amount of external resistance, to compensate for the changes of resistance in an arc, but when you come to get a drop of 110 or 150 volts between generator and arc you have entirely different conditions. Then, the regulating effect of the external resistance is too great, and the arc surges up and down slowly, and is a troublesome thing to deal with, and requires different mechanism for its regulation.

At any rate, very little work has been done in that line with large arcs, and there is a certain amount of experimental work that has to be done before searchlights can be successfully operated on those circuits. At least such has been the case with other arcs where no difficulty had been anticipated, but when they were put on high-voltage circuits and sufficient resistance put in series with them to bring the voltage across the terminals down to the proper point, the arc surged up and down in a very unsatisfactory manner, and considerable trouble was experienced. I mention this simply as tending to show that some experimental work must be done before introducing high voltages on board ship.

A MEMBER:—In regard to the point made by one speaker as to the undesirability of using electric drive for auxiliaries, either for central station or on board ships, it seems to me there is a point there that is overlooked. If we can use electric auxiliaries and get the power to drive those for say 30 pounds of steam per brake horse-power as against 119 that it takes for the steam driven auxiliaries, we have got there a matter of 80 pounds of steam per horse-power hour, which we can use if we wish to as live steam to heat our feed water. On the other hand, the only way of heating feed water is really to save some of the heat in the exhaust steam that we are wasting by using non-condensing pumps, so that we would be in better mechanical condition to use our steam in condensing steam engines and then heat our feed water in the boilers, or if we want to avoid the strain in the boilers, use a little of the extra live steam we are saving to heat our feed water, and still use the electrically driven auxiliaries.

MR. LIEB:—The gentleman should not understand me to say that I was opposed to electrically driven auxiliaries. I simply wished to point out one difficulty in connection with their use which had not before been presented.

THE PRESIDENT:—Is there any further discussion on the paper? If not, Mr. Greene will take up the various points that the speakers have stated.

MR. S. DANA GREENE:—I want to thank the members of the society for the evident interest they have taken in the paper as shown by the discussion which has followed, and which I can assure you has been most interesting to me. I have made notes of a number of points, and I think that some of the points raised have been perhaps due to a little misunderstanding. First, with reference to Prof. Thomson's remarks about the high possible economy of small simple steam engines, it might appear from what he left unsaid, more than from what he said, that his remarks were in contradiction of his statement that the electric drive was the only thing to use on board ship. It at once occurred to me, what no doubt Prof. Thomson had in mind, that the high steam pressures necessary to obtain these economies, makes this form of steam drive absolutely impracticable on board ship. I do not think any man who has had any experience afloat would question that statement for a moment.

Lieut. Walling, in referring to the improvement of the efficiency of certain small engines on board ship, gave, unintentionally, I think, an erroneous impression that the engines he spoke of included *all* the various auxiliaries; whereas I am quite sure that the particular engines to which he referred as having improved in economy were only those operating the electric generators. As I pointed out in the case of the *Minneapolis* there are between 30 and 40 auxiliary engines, and in a great many of them, as some other gentleman has already pointed out, the conditions of service are such that they must inevitably be un-

economical, giving a very low average economy as this test showed I think Lieut. Walling has rather missed the point with respect to the anchor hoist or winch and the steering engines. It seems to me not a question of the reliability of the motor, but of the reliability of the *mechanical application* of the motor to the operating mechanism. I can illustrate this perhaps by reference to the experience on the great lakes in towing vessels. The introduction of the enormous barges carrying five or six thousand tons of ore has revolutionized towing, and the old-fashioned method, which still prevails on our coast, is laughed at on the lakes to-day. They found that the pitching, which is the condition Lieut. Walling spoke of, will snap any steel hawser. They now have a towing engine which automatically takes up the slack or pays out the hawser as the vessel pitches. I have seen tows of four and five of those vessels each carrying five or six thousand tons of ore in a heavy sea on the lakes, when the captain of an ordinary tow along our coast would have scuttled for harbor very quickly, leaving his tow adrift perhaps.

I also question the difficulty of insulating for 160 or 200 volts. I do not think we need consider that seriously. That is to say, I for one am not prepared to admit, nor do I think that any man who has had experience in wiring is prepared to admit, that a piece of wiring work on board ship or anywhere else cannot be installed to give a high insulation resistance for 200 volts. I think it is largely a mechanical question. A great many of the troubles in the wiring of ships, are due to mechanical injuries to the cable. By mechanical injuries I refer not only to cuts and abrasions, but to the rapid deterioration of the insulation due to heat or oil. We all know the effect of heat and oil on rubber insulation. My suggestion, as a remedy for this difficulty, made a number of years ago while still in the service, was to run a series of ducts fore and aft in the ship while building, with branches or "risers," in every compartment, using these ducts simply as runways for the wires. I think it would be a great protection if that were done.

Capt. Millis, I think, has suggested the possible use of alternating current apparatus on board ships, and I think that is quite possibly one of the developments of the future. One point which will have to be thoroughly worked out, is the control of induction motors under varying conditions of load and speed; a control which, as Mr. Leonard has very clearly pointed out, must be absolute and exceedingly fine. If I am not mistaken the *Brooklyn's* turrets have been started and stopped thirty times in 3 inches of arc.

LIEUT. WALLING:—Thirty-seven times in a minute.

MR. GREENE:—That gives you the idea of the fineness of the control. That is the whole secret of pointing guns. The man has got to feel that he has absolute control of his turret or his 8″ or 12″ gun; the nearer the gunner can handle it as he does a

rifle, automatically, so to speak, without having his eye distracted from his sights, the better shooting will be done.

With reference to searchlights, the point the gentleman last speaking made as to the arc not operating properly with a large resistance in circuit (on 160 or 200 volts circuit,) may be entirely correct. I confess I have not had experience on that point; but if it is true, my suggestion would be not to sacrifice the rest of the plant, but to put in a separate machine for operating the searchlight. The searchlight circuits are run independently on board ship to-day. Install a separate machine for each of them; it would not need to be a large machine, nor would it have to be used very often. I quite agree with the suggestion that searchlights should be introduced largely in our coast fortifications, and as a matter of fact a great many were introduced during the late war. But the conditions of use of the search lights at Santiago were very different from those which obtain, for instance, off Sandy Hook. At Santiago, ships on the outside were directing a beam on the entrance, not over a couple of hundred yards wide; maintaining it there and lighting up the entrance so brilliantly that vessels lying three or four miles on one side or the other of the beam of light could see a small boat distinctly at the harbor entrance. There is not the slightest doubt that if Admiral Cervera's fleet had attempted to come out at night, it would have been discovered by our fleet as quickly as it was when it came out in the daytime. It is one thing to put a searchlight beam on a stationary object, when we know where it is, and keep it there. It is quite another thing to pick up a moving object, particularly a small moving object painted a "war color," not knowing where to locate it. I think in almost every case where torpedo boats have made practice attacks on war vessels, the latter attempting to defend themselves by searchlights, the torpedo boats have won; in other words, they have been able to discharge a signal rocket within "torpedo distance" of the ship before they were discovered. It requires great practice, and I know from personal experience that it is very difficult, to pick up even a comparatively large vessel when you have got to look for her and do not know where she is, and you are sweeping the horizon with the arc. Therefore, I do not think too much stress should be placed on searchlights for shore work. Undoubtedly if the vessel is once discovered they are very useful in keeping her exposed as a target and in confusing those navigating the vessel.

The question of properly trained men for the navy is purely a business problem. If you are operating a large central station, using triple expansion engines and large direct coupled units, you expect to have a better man in charge than in the case of a small station with simple engines and belted generators. The navy cannot expect to secure good men in time of peace for routine work unless they pay for them; I think that they *can* secure a very excellent

class of men if they raise their wages on board ship, so that they are comparable, for instance, with those of first-class machinists who, if I am not mistaken, receive somewhere between $75 and $100 a month and their rations, with no rent to pay; Uncle Sam gives them their hammock-space free. The amount of knowledge and intelligence required of men to handle electrical apparatus on board ship is not excessive. Practical operating men are wanted; and if the navy is willing to pay for them, I have not the slighest doubt that they can be obtained and that they will remain in the service.

It seems to me that Mr. Lieb's point as to the question of using the exhaust steam from the steam auxiliaries for heating feed water is, as the gentleman has pointed out, entirely covered by my figures, if they are correct. If the saving which I have indicated by these figures (and I think that I have been conservative) is correct, then no possible saving, such as Mr. Lieb suggests, can make up for this difference. I think the same is true of the auxiliaries in a central station, though perhaps to a less degree, because the conditions of operation in a station are less severe than on board ship. I know of one station which has no steam cylinders outside of the main generating engines except a reserve steam feed pump, and I think that the economy of the station, including the auxiliaries, compares favorably with any other station in the country. Of course, the load factor cuts a very important figure in central station economy.

One gentleman has suggested that we should have duplicate plants on board ship. We might say the same thing of the boilers and the engines. I pointed out that if a plant for the auxiliaries is to be used on the scale suggested, we must consider it as one of the vitals of the ship, and it must be below the protective deck, just as the boilers, engines and magazines are. If it is so located, I think that the chances of its being disabled are certainly no greater than the chances of the engines or boilers being disabled. The present practice in the navy is, to allow about one-third reserve capacity; I do not think in a plant as large as the one suggested, 1,000 horse-power, it would be necessary to have so much. Possibly two spare units would be installed instead of one, as I have suggested.

I think there is a little misunderstanding on the part of both Mr. Martin and Capt. Millis as to the cable cutting off Cuba. I happened to see some of that myself. A regular cable steamer was for several days cruising off Santiago, trying to pick up a cable, and General Greely was cabling from Washington every day, wanting to know why it was not cut. The reason was that they could not find it, and the reason they could not find it was that the bottom was coral rock, covered with all sorts of tropical submarine growth; the cable was embedded within a mass of these coral rocks, and when it was finally raised it was found to be three or four times its normal size. Naturally this

cable steamer had to keep out of the range of the guns in the Morro Castle. She was grappling in 800 or 1,000 fathoms of water, although only three or four miles off the shore. That was a "professional" vessel with "professional" men on board. The men engaged in the cable cutting expeditions at Cienfuegos, as Capt. Millis pointed out, were obliged, in order to get the shore end of the cable to run in close to the beach, because the water deepens very rapidly there, as at Santiago. When the cable was once lifted and put on the rollers of the launch it was cut probably as quick as anybody could have cut it under the circumstances, and I think it was one of the pluckiest and bravest acts of the whole war. There was no excitement of battle about it; those men had to work under a steady fire from rifle pits, not 100 yards away.

Mr. Martin referred to my statement in reference to range finders and telephones. I was very careful about the language I used. I said "there are devices, like the range finder and telephone, which while of great utility, have not yet demonstrated that they can be relied upon at all times." I think the best demonstration of the truth of my statement is, that they were not used during the battles of Manila and Santiago. They are of great utility; we all know that, and all admit it. They were not used in battle to any extent because they were found not to be reliable or serviceable under these conditions. In the case of the telephone, it is not merely a question of the reliability of the instrument. A man may be stationed near a blower or near escaping steam, or among the many rattling noises on board ship, and any telephone is absolutely useless under such conditions. The telephones may be in perfect working order so far as their condition of electrical operation is concerned, but they cannot be used. The same way with the range finders. The range finders have to be placed at the end of a base line of known length on board ship; communication has to be maintained between these stations by telephone; not only between them but with the conning tower and the various indicators around the ship. I have no doubt that one reason why neither the telephone nor range finder were used more in those actions than they were, is because under certain conditions there is so much noise that it is absolutely impossible to hear the telephone at all. Perhaps sometime we shall have enclosed telephone booths aboard ship, as we have on shore, and then it can be used at any time.

THE PRESIDENT.—I think that I shall be voicing the general feeling and sentiment of the meeting if I extend to Mr. Greene the thanks of the INSTITUTE for the paper that he has kindly brought before us. There is nothing further before the INSTITUTE, and a motion to adjourn will now be in order.

[Adjourned.]

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